The RADIO AMATEUR'S HANDBOOK

A MANUAL OF AMATEUR HIGH-FREQUENCY RADIO COMMUNICATION

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The Radio Amateur's HANDBOOK

A Manual of Amateur High-Frequency Radio Communication

BY THE HEADQUARTERS STAFF
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Chapter Five

HIGH-FREQUENCY RECEIVERS

WHATEVER one's principal interest in amateur radio, be it operating a complete station or experimenting with a variety of circuits, the basic piece of apparatus is a good receiver. The building of the complete station is always a process of evolution. Most amateurs start out with a simple receiver, listening in on it until they become proficient in the art of tuning in high-frequency signals, and at the same time learning the code in preparation for obtaining a transmitting license. The amateur has the choice of building his own receiver or of purchasing one of the several amateur-band manufactured receivers now available at reasonable prices. Many amateurs prefer to build their own, not just for reasons of economy, but more for the experience and to acquire the intimate knowledge of operation that they obtain. Instructions for building chosen types of receivers of proved high performance and descriptions of representative manufactured receivers are contained in this chapter.

The first receiver need not be an elaborate one; in fact it is better to pick out a simple and inexpensive set for the initial attempt. It will be relatively easy to get such a set working and, even though it is built with the full knowledge that it will not be the permanent receiver of the finished station, the investment in the equipment for it will not be wasted. Most of the parts used in simple receivers can be used equally well in more intricate sets later on. In this chapter several types of receivers are described. All of them are thoroughly practical outfits, capable of giving excellent service if carefully built and correctly operated.

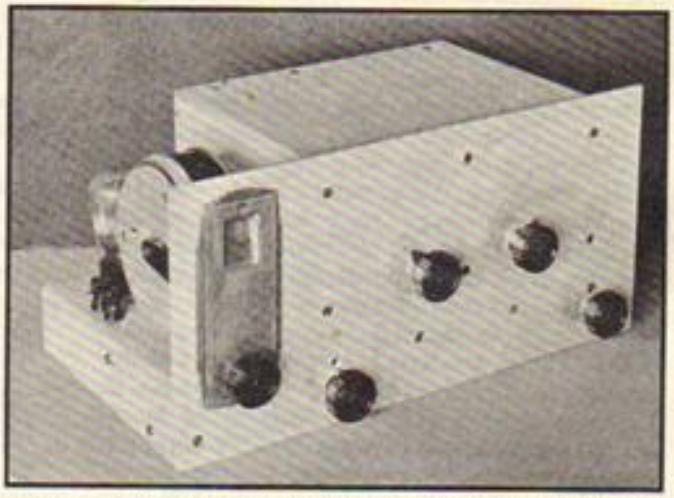

FIG. 501 — A MODERN THREE-TUBE TUNED R.F. AMATEUR-BAND RECEIVER DESCRIBED IN THIS CHAPTER

It comprises a stage of t.r.f. amplification with controlled sensitivity, a stable regenerative detector and one-stage audio. It uses heater-type tubes for a.c. or 6-volt d.c. operation and is adapted to conversion to a single-signal type superheterodyne, as shown later in the chapter.

The tuning dial is placed at the left so the receiver can be operated without getting in the way of papers, log books, etc. To the right and below the dial is the regeneration control. The two upper knobs are the band-setting condensers. The sensitivity control is in the lower right-hand corner. The audio tube and the 'phone binding posts can be glimpsed behind the drum dial on the sub-base.

Receiver Characteristics

The three important general characteristics of a receiver are its selectivity, its sensitivity and its fidelity. These three are inter-dependent, with selectivity the controlling factor. The *selectivity* is the receiver's ability to discriminate between signals of different frequencies. The *sensitivity* is the minimum r.f. voltage input required to give useful output. The *fidelity* is the proportionate response through the audio-frequency range required for a given type of communication.

Sensitivity is fundamentally limited by the noise output, which in turn is directly related to the selectivity, being less as the selectivity is greater. Only signals that are detectable above the noise background are useful; therefore, reducing the noise output by increasing the selectivity improves the effective sensitivity in proportion. Sensitivity is thus not solely dependent on the amplification in the receiver but on the combination of amplification and selectivity. The fidelity requirement in amateur receivers is essentially different from broadcast receiver requirements, although this is not generally realized, and is set by the minimum required for intelligibility. For c.w. telegraph reception of hand-keyed signals (say up to 30 words per minute) adequate fidelity for intelligible reception can be obtained with selectivity such that the receiver's equivalent band width is but 20 cycles or less; for 'phone reception with usable intelligibility the equivalent band-width may be as little as 120 cycles, as has been determined by actual measurement of a highly-selective single-signal receiver. It is therefore evident that the most important receiver characteristic is the effective selectivity; for the higher the selectivity, the greater can be the amplification and the higher the effective sensitivity, to the

limits imposed by the requirement of intelligible output.

Types of Receivers

Two types of receivers meeting the requirements of general amateur work are the simple regenerative receiver (autodyne) and the superheterodyne. Special types for ultra-high frequency work are treated in Chapter Nine. In the regenerative receiver there is r.f. feedback in the detector circuit with the amount of this regeneration controllable to give either high amplification and selectivity without oscillation, or to give these together with oscillation to provide the heterodyne for beat-note c.w. reception, as has been explained in Chapter Four. The simplest form of receiver is just one tube in a regenerative detector circuit, although the output available from such an arrangement is so small as to be generally unsatisfactory. A single stage of audio amplification following the detector gives more satisfactory results. A still further improvement is a stage of tuned radio-frequency amplification preceding the detector. This increases sensitivity and gives somewhat greater selectivity, provides helpful isolation of the regenerative detector from the antenna circuit and allows sensitivity control ahead of the detector circuit.

Whereas the regenerative receiver's r.f. circuits handle the signal at incoming frequency, in the superheterodyne type receiver the incoming signal is converted to a lower radio frequency and then amplified in intermediate circuits prior to conversion to audio frequency in the second detector. As explained in Chapter Four, this method allows greater r.f. amplification and the attainment of higher selectivity, since both of these are more readily obtained in the intermediate-frequency (i.f.) amplifier. This applies particularly to the single-signal type superheterodyne, originally developed in the A.R.R.L. laboratory and described in this chapter, which obtains extremely high selectivity in the i.f. circuits either by means of a variable-selectivity quartz crystal filter or by controllable regeneration in an i.f. stage.

The simple regenerative type receiver is less complicated than the superheterodyne, of course, and is accordingly less expensive. Until one has gained experience it is advisable to work with the simpler receiver, progressing later to the superheterodyne type. In fact, a suitable regenerative receiver can be used as the foundation of the superhet, as will be illustrated by a typical example.

Tuning Arrangements and Band Spreading

Since the amateur frequency-bands comprise narrow slices of territory widely separated, it is not possible to cover them all effectively with one coil and condenser in the tuner. Many schemes have been evolved to provide suitable coils and coil sockets. The use of a tube-base or a special form of larger size plugging into a tube socket is now almost universal. Coils of this type are pictured later on with the constructional details of the receivers in which they are used. Larger coils with a horizontal row of plugs fitting into a similarly-arranged row of sockets are also used in some cases. The important requirements are that the coils should be readily interchangeable; the contacts should be positive; the coils should be mechanically strong so they will not be deformed in handling; and they should be small in diameter in order to avoid the existence of an extensive magnetic field around them.

Tuning condensers used in high-frequency receivers are much smaller than those employed for the broadcast band and lower frequencies. A 350- or 250-$\mu\mu$fd. condenser will, at high frequencies, cover so much territory that tuning becomes extremely difficult, because the amateur bands occupy only a few divisions on the usual 100-scale dial. Many amateurs remove plates from standard-sized condensers to reduce the maximum capacity, or else use midget condensers, which can be obtained in a variety of capacities. If the receiver is to cover all frequencies between 20,000 and 3000 kc., common practice is to use a tuning condenser rated at 150 $\mu\mu$fd. with three plug-in coils, but even this arrangement crowds the amateur bands in a very small proportion of the dial scale. Most amateurs prefer to spread the bands over a large part of the dial.

The amateur bands are not entirely in harmonic relation, and therefore a condenser which spreads one band satisfactorily will not give the same spread on others. In order to make each band cover a large number of dial divisions, the ratio of maximum to minimum capacity must be different for each band. One method is to use plug-in midget tuning condensers which are changed each time the coils are changed. The standard midget condensers will not always work satisfactorily, and plates must therefore be removed until each band is spread as much as desired. Since this method is somewhat cumbersome mechanically, its use is not very practical if the receiver has a tuned r.f. stage.

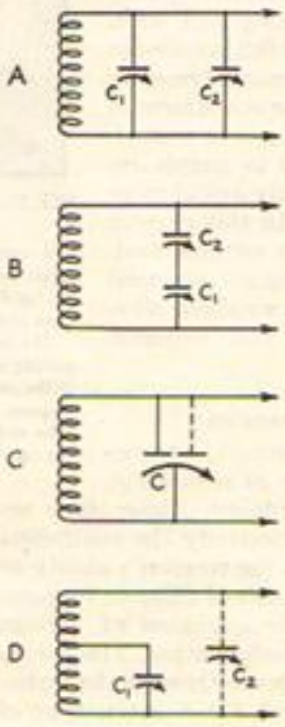

FIG. 502 — THE ESSENTIALS OF FOUR POPULAR BAND-SPREAD SYSTEMS

Several widely used band-spreading schemes are shown in Fig. 502. At A is the parallel-condenser method. C_1 is the tuning condenser, usually with a maximum capacity of about 25 $\mu\mu$fd. C_2 is a "band-setting" condenser; its maximum capacity should be at least 100 $\mu\mu$fd. and may be larger. The setting of C_2 will determine the minimum capacity of the circuit, and the maximum capacity will be the maximum capacity of C_1 plus the setting of C_2. A different maximum-to-minimum capacity ratio can be chosen to give good band-spreading on each band.

The series-condenser method is shown at B. As explained in Chapter Three, the total capacity of two condensers in series is less than that of either. C_1 again is the tuning condenser. It should have 100 $\mu\mu$fd. or more maximum capacity. C_2 is the band-setting condenser and is preferably small, perhaps 25 $\mu\mu$fd. The maximum-minimum capacity ratio in the circuit will be determined by the setting of C_2. The minimum capacity changes very little for any setting of C_2, but the maximum capacity can be varied over quite a range, depending upon the ratios of the capacities of the two condensers.

At C is another arrangement which makes use of a "split-stator" tuning condenser — one with two separate stationary-plate sections and a single rotor. One of the stator sections is made small enough to give good band spreading on the 14- and 7-megacycle bands, and the second stator section, when connected in parallel with the small stator, will give good spread on 3500- and 1750-kc. The dotted connection for the two lower-frequency bands shown in C can be made by using a jumper in the low-frequency coil forms, the change being automatically made when the coils are plugged in. This method is used in the two-tube receiver described later in this chapter.

The tapped-coil system at D is used in several commercial amateur-band receivers and has also been adopted by a number of amateurs in home-built sets. Condenser C_1 may be fairly large — 100 $\mu\mu$fd. or so — but will give good spread on any band if the right size of coil is chosen and the tap to which the stator plates of the condenser are connected is made at the right place. This system is a little more tricky to adjust than the first three. Condenser C_2 is not strictly necessary but will be found helpful in getting the spread just right, and its use will help eliminate some of the cut-and-try in winding the coils. It should have a maximum capacity of about 25 $\mu\mu$fd.

Regeneration Control

Almost any arrangement of the tickler coil and feed-back control can be depended upon to give similarly loud signals, but some of them have the advantage of being more convenient and of permitting adjustment of regeneration without detuning the signal. It is also a great advantage if the regeneration control is absolutely quiet in action; if it permits a gradual adjustment up to and past the point of oscillation; and if it permits the tube to oscillate gently all across the frequency band on which the receiver is working without the necessity of touching anything but the tuning control.

Fig. 503 shows two ways in which regeneration may be controlled with a screen-grid detector. At A the regeneration control is a variable condenser having a maximum capacity of 100 or 150 $\mu\mu$fd. It acts as a variable by-pass between the low-potential end of the tickler coil and the cathode of the tube. If the by-pass capacity is too small the tube will not oscillate, while increasing the capacity will cause oscillations to start at a certain critical value of capacity. This method of regeneration control is very smooth in operation, causes relatively little detuning of the received signal and, since the voltage on the screen-grid of the tube is fixed, permits the detector to be worked at its most sensitive point. The sensitivity of a screen-grid detector depends a great deal upon maintaining the screen-grid voltage in the vicinity of 30 volts.

At B regeneration is controlled by varying the mutual conductance of the detector tube through varying its screen-grid voltage. The regeneration control is usually a voltage-divider — or so-called "potentiometer" — with a total resistance of 50,000 ohms or more. This circuit causes more detuning of the signal than A, and the resistor is likely to cause some noise unless by-passed by a large capacity (about 1 μfd.) at C. In A, condenser C may be .5 μfd. or larger. With circuit B it is necessary to adjust the number of turns on the tickler coil to make the tube just start oscillating with about 30 volts on the screen-grid if maximum sensitivity is desired.

Both the methods shown in Fig. 503 may be applied to three-electrode detectors, although these tubes have been largely superseded as detectors by the more sensitive screen-grid tubes. To use method B the regeneration-control resistor should be placed in series with the plate of the tube and it need not be used as a voltage-divider but simply as a series variable resistor. It can also be used as a series resistor when controlling a screen-grid tube. Another type of regeneration control, more suitable for lower radio frequencies, is shown in the five-tube superhet described later.

In all methods it is essential that the tickler be mounted or wound at the filament end and not the grid end of the tuning coil. In the interests of smooth control it will be found advisable to use just as few turns on the tickler as will allow the tube to oscillate easily all over the tuning range. If the tube starts oscillating with a sudden thump instead of a smooth rushing noise, a lower value of grid lead resistance should be used.

Radio-Frequency Amplifiers

A regenerative detector followed by a stage or two of audio-frequency amplification, when used for c.w. telegraphic work, will bring in amateur signals from all over the world on the higher

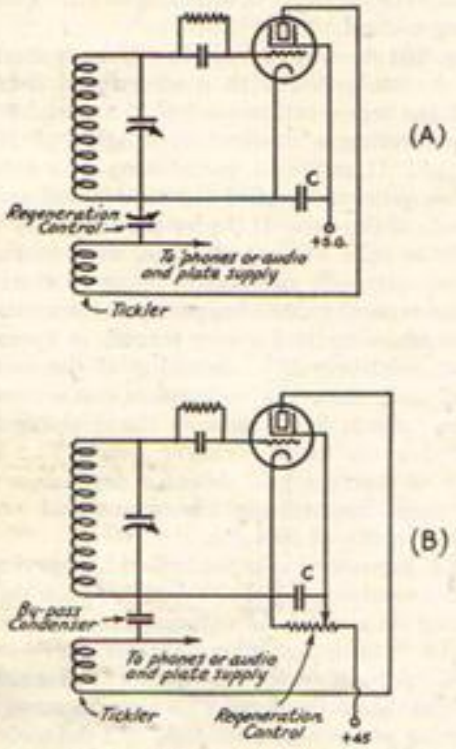

FIG. 503 — CONDENSER AND RESISTOR CONTROL OF REGENERATION

frequencies. For such work, the sensitivity of this type of receiver usually proves to be ample. At times, however, a radio-frequency amplifier ahead of the detector is very desirable. The increase in sensitivity and selectivity provided by it can be put to good use in the reception of amateur radiotelephone signals. A further advantage of such an amplifier is that it isolates the detector from the antenna, reducing the radiation from the detector in an oscillating condition and making it impossible for the antenna, swaying in a wind, to cause the received signal to waver. A radio-frequency amplifier is also of considerable service in the elimination of "dead-spots" — points on the tuning dial at which the antenna, coming into resonance, might otherwise stop the detector from oscillating.

The three-element tube is almost useless as a radio-frequency amplifier in the short-wave receiver. The modern screen-grid tube, however, is most effective providing the circuit in which it is used is a suitable one. One arrangement for the radio-frequency amplifier is that in which the grid circuit for the first tube comprises a resistor or choke connected directly between the antenna and ground. This so-called "untuned" radio-frequency amplifier isolates the detector from the antenna and gives some amplification, but it does not improve the selectivity of the receiver. Rather, it makes the receiver susceptible to interference from any near-by powerful amateur or broadcast transmitters. Careful proportioning of the choke in the grid circuit makes it possible to avoid interference from broadcast stations, but not from other amateurs. If local interference is not likely to be troublesome an untuned r.f. stage will be found helpful. It is not hard to install because no shielding will be necessary.

Fig. 504 shows two methods of connecting an untuned r.f. amplifier to a regenerative receiver. That at A uses transformer coupling between the r.f. stage and detector, while at B impedance coupling is shown. Transformer coupling is preferable because the number of turns on the two coils can be proportioned to give the greatest amplification (usually the primary, *P*, should have about ⅔ as many turns as the secondary, *S*), and because the plate voltage for the r.f. tube is kept away from the detector circuit. It requires coil forms with enough pins to take care of primary, secondary and tickler, however. With impedance coupling, as at B, the detector coil must be isolated from ground by means of the by-pass condenser *C*. The grid leak must be connected between grid and filament instead of across the grid condenser, since the latter blocks the positive plate voltage from getting to the

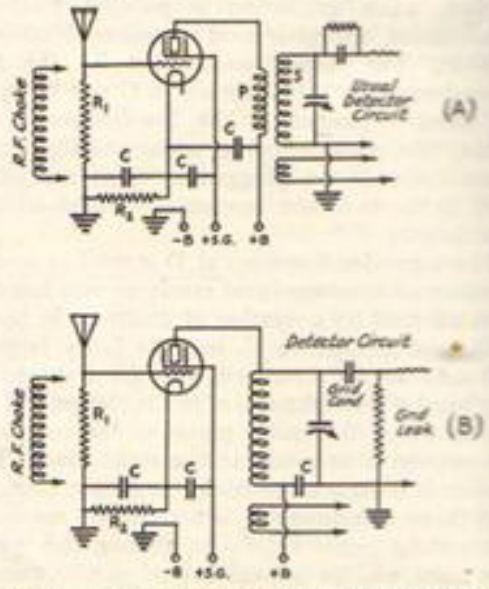

FIG. 504 — UNTUNED R. F. AMPLIFIER DIAGRAMS

A transformer coupling, B, impedance coupling to detector. A resistor, R_1, having a resistance of 10,000 to 20,000 ohms is connected between the grid of the screen-grid amplifier tube and ground. An r.f. choke, consisting of perhaps 100 turns of small wire wound on a form about the size of a pencil, can be substituted for the resistor if interference is experienced from local broadcast stations. Resistor R_2 gives the tube the correct operating bias, as explained in a later section of the text. If the tube filament is directly heated a battery of the proper voltage should be substituted for the resistor, and the ground connection should be brought to the filament of the tube.

grid of the detector. Because of leakage across the grid condenser this circuit may be noisy unless a good mica condenser with extremely high insulation resistance is used.

Rather complete shielding is always required when the input circuit to the r.f. amplifier tube is tuned. For this reason the tuned r.f. type receiver is somewhat more costly and more difficult to build. In one form such a receiver has two separate tuning dials — one for the input circuit to the r.f. tube and one for the input circuit to the detector. The obvious difficulty in tuning these two controls has led to the development of receivers in which the two tuning condensers are "ganged." The construction of a receiver of this type is a work requiring a little more skill, and had best be attempted after experience has been gained with the simpler types.

Shielding

The purpose of shielding is to confine the magnetic and electrostatic fields about coils and condensers so that those fields cannot act on other apparatus, and to prevent external fields from acting upon them in turn. Chapter Three has explained the nature of these fields. They can be confined by enclosing the apparatus about which the field exists in a metal box. The effectiveness of the shield depends upon the metal of which it is made and upon the completeness of contact at the joints. At radio frequencies the best shield is one made of a low-resistance nonmagnetic metal, such as copper or aluminum, because the losses in it will be low. The magnetic fields about the apparatus enclosed in the shield cause currents to flow in it, and since the flow of current is always accompanied by some loss of energy the shield in effect causes an increase in the resistance of the tuned circuit. The lower the resistance of the shielding material the lower will be the energy loss. At low frequencies, such as those in the audio range, copper and aluminum are ineffective for shielding and iron must be used.

The increase in resistance caused by shielding also depends upon the proximity of the apparatus inside the shield to the walls. Coils in particular should be spaced from the walls in all directions by at least a distance equal to the coil diameter. For this reason small coils are much to be preferred to large ones if the set is to be kept reasonably small. The losses in the shielding due to electrostatic fields are negligible in comparison to those caused by magnetic fields, so condensers can be mounted right on the walls of the shield if desired.

To be effective a shield must be grounded. Although an actual ground connection always will be best, it is sometimes sufficient to connect the shielding to a point in the receiver at zero r.f. potential, such as the negative side of the plate supply. Another point is that shields must be complete for each amplifier stage or group of apparatus shielded. Do not attempt to use a single sheet of metal to form a common wall for two shields as shown in Fig. 505; such a wall will actually couple the two shielded groups or pieces of apparatus together instead of shielding them from each other.

There are two general methods of shielding. One is to group all the apparatus forming a single stage of amplification and put it in a single shield. The three-tube receiver described in this chapter is an example of this type of shielding. The second method, exemplified by the manufactured receivers described later, is to use individual shields around each piece of apparatus, connecting them by shielded leads where necessary. Only those leads which are not at zero r.f. potential need be shielded. Each method will give good results, and the choice is usually dictated by mechanical considerations.

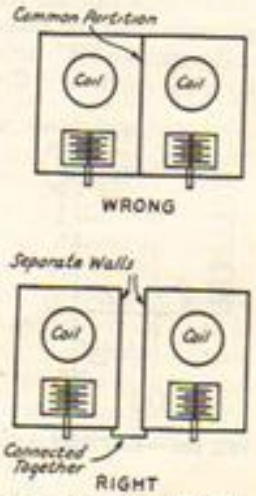

FIG. 505—SHIELDING ALWAYS SHOULD BE COMPLETE ABOUT EACH PIECE OR GROUP OF APPARATUS SHIELDED

Do not attempt to use a common partition between shielded stages, especially when one of them contains a regenerative detector or oscillating circuit.

Although, as we pointed out in the previous section, shielding is not necessary if no tuned r.f. amplifiers are used, it is often helpful. A metal cabinet about a simple receiver will prevent direct pick-up of signals by the coils and wiring of the set, and it will also keep out "induction hums" from unshielded house wiring.

Amplifier Biasing

Practically all amplifiers, both audio and radio frequency, must be operated with a minimum negative voltage between the grid and cathode of the amplifier tube. This *bias* voltage may be obtained from a battery or from a suitable voltage drop through a resistor in the circuit. Fig. 506 shows these two methods in an elementary fashion.

In general, the battery-bias method should be used with tubes having directly-heated cathodes (*filament-type* tubes). In such cases one side of the filament is connected to ground. In order to connect the bias battery in series with the lower end of the transformer secondary or whatever may be in the grid circuit of the amplifier tube, it is necessary to insulate point X in Fig. 506-A from ground. Condenser C is used to provide a low-impedance path to the filament should the bias battery develop appreciable internal resistance. It should be about .01 μfd. in r.f. circuits and 1 to 2 μfd. in audio circuits.

The second method, known as *cathode resistor biasing*, is shown at B. This method does away with the extra bias battery, and is particularly adapted to tubes with indirectly-heated cathodes (*heater-type* tubes). With this method point *X* is grounded and the cathode is isolated from ground and negative "B" through the biasing resistor *R*. By-pass condenser *C* will have the same values

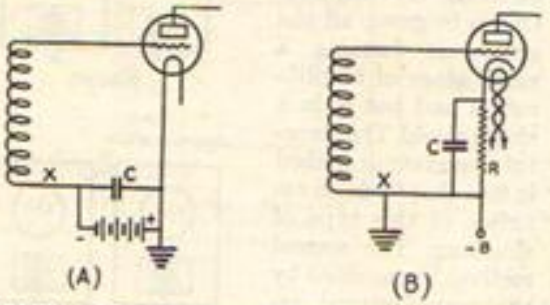

FIG. 506—BATTERY AND CATHODE-RESISTOR BIASING

as in A. When plate current flows through the tube there will be a voltage drop through *R* which makes the cathode more positive than the grid—in other words, puts negative bias on the grid. The right value for *R* can be calculated by Ohm's Law, knowing the bias voltage required and the total space current through the tube. The space current is the sum of the plate current and all currents that may be taken by auxiliary grids in the tube. For example, a certain pentode tube requires a bias of 10 volts with 150 volts on the plate and screen-grid; at this plate voltage the plate current will be 15 ma. and the screen-grid current 5. The bias resistance required will be:

$$R = \frac{10 \text{ volts}}{.02 \text{ amp.}} = 500 \text{ ohms.}$$

Cathode-resistor biasing can be used with tubes having directly-heated filaments provided a separate source of filament-heating is used with each stage so biased. This is often done in a.c.-operated receivers having an audio power output stage, the power tubes being heated by a separate filament winding on the power transformer.

Audio-Frequency Amplifiers

For reception of amateur signals, it is unnecessary and even undesirable to have the frequency-distortionless audio amplification which is the aim of designers of broadcast receivers. Audio transformers with "flat" frequency characteristics are therefore not required. In fact, a transformer which has a decided "hump" at some portion of its frequency curve is preferable for c.w. reception, particularly if the hump is in the neighborhood of 1000 cycles. Such a transformer will provide some audio-frequency selectivity, since it amplifies one frequency a great deal more than others.

For 'phone reception the same principles should be applied as for ordinary amplification. Plate voltage and "C" bias on the amplifier tubes are important, and should be those recommended in the instruction sheets accompanying the tubes or may be taken from the table. Since, in amateur radiotelephony, we are concerned only with the transmission and reception of speech, it is unnecessary that the equipment be capable of handling frequencies higher than about 3000 cycles per second. Frequencies above this, indeed, may merely cause interference and can well be eliminated.

The receivers described in detail in this chapter are intended to be used with headphones, although they can operate a loud-speaker at low or moderate volume. For satisfactory loud-speaker

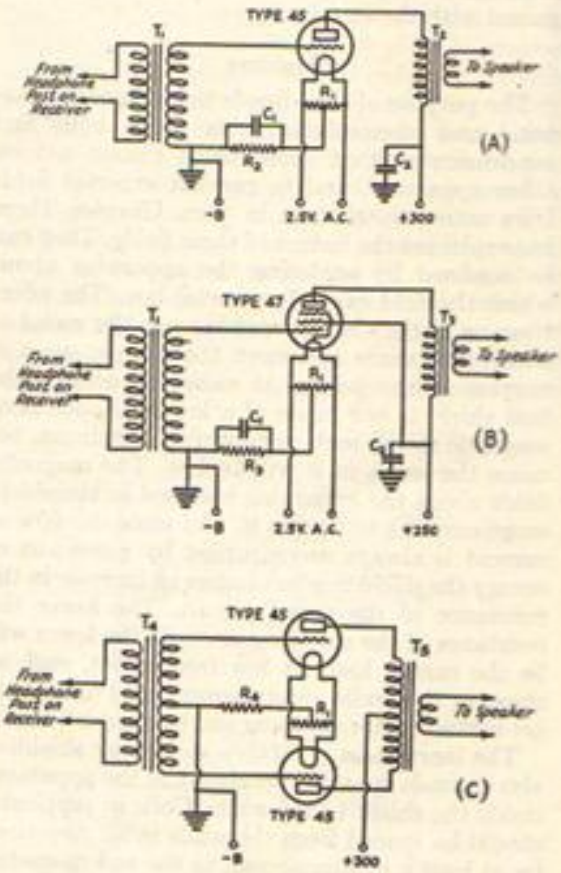

FIG. 507—AUDIO POWER AMPLIFIERS FOR LOUD-SPEAKER OPERATION

A—using a single Type 45 tube, B—a single 47 pentode, C—two 45's in push-pull. Transformer T_1 is an ordinary audio transformer having a turns ratio of 2:1 or 3:1. T_2 is an output transformer designed to couple a 45 tube to the loud-speaker being used. T_3 is for coupling a 47 to the speaker. T_4 is a push-pull input transformer and T_5 a push-pull output transformer for a pair of 45's. It is necessary to know the impedance of the loud-speaker in order to purchase the right type of output transformer in all three cases. R_1 is a 20-ohm resistor, tapped at the center. R_2 is 1500 ohms, rated to carry approximately 50 ma. R_3 is 450 ohms, also to carry about 50 ma. R_4 is 750 ohms, rated at 75 ma. or more. Both C_1 and C_2 should be 1 to 2 μfd. C_3, which must be rated to stand the full plate supply voltage, may not be needed if the plate voltage for the amplifier comes directly from a filter condenser in the power pack.

operation, however, a power audio stage should be used. A number of diagrams for this purpose are given in Fig. 507. These amplifiers had best be a.c.-operated, using power supplies of the type described in Chapter Ten. Other tubes than those shown can be used provided the voltages are changed to the recommendations in the tube table.

Receiving Tubes

The large number of types of receiving tubes available often causes considerable confusion to the beginning amateur because it seems difficult to choose the proper ones for the contemplated receiver. Many of them, indeed, have little application in amateur work. Modern receiving tubes are grouped into three classes, depending upon the type of service for which they are intended. One group is for dry-cell operation and is characterized by tubes with 2-volt directly heated filaments which take very small currents. The second group has filaments designed for use with a 6-volt storage battery. Most of the tubes in this group have indirectly-heated filaments. The third, or "a.c." group, has filaments which take rather heavy currents at 2.5 volts a.c. In this group the tubes used as r.f. amplifiers and detectors have indirectly-heated filaments while the power audio amplifiers have directly-heated filaments.

In each group will be found general-purpose three-element tubes which are useful as detectors, audio amplifiers and oscillators; screen-grid amplifiers (usually two types of these, one with the "variable-mu" feature, the other without); and various kinds of power amplifiers — triodes, pentodes and special tubes for Class B amplifiers (see Chapter Eight).

In addition to these groups, there are also several older types such as the 99 and 01-A which have been superseded by the newer and better tubes and are now only used for special purposes.

From the above it is obvious that the first question to be decided is that of filament supply. If a.c. is available it is undoubtedly best to use the heater-type tubes, not only because no batteries will be required but because, type for type, these tubes are better than the others. On the other hand, an all-d.c. set will have no "hum troubles."

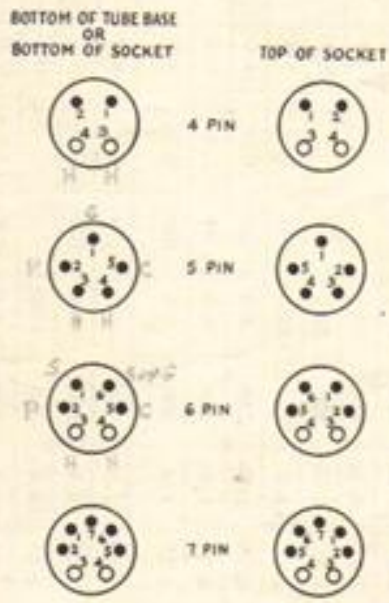

FIG. 508 — TUBE SOCKET CONNECTIONS FOR RECEIVING TUBES

The diagrams in the left-hand column are for the sockets as viewed from the bottom, those in the right-hand column as viewed from the top. The pin numbering is according to the system adopted by tube manufacturers (R.M.A. standard). The accompanying table indicates by number the tube element connected to each socket pin, also to the cap on top of the tube when there is one. It should be noted that some tubes have a larger base than most, in which case the pin arrangement is the same but of greater radius requiring a larger socket.

Fig. 508 shows the socket connections for the tubes listed in the table. The symbol for each type of tube also is shown.

Receiver Construction

The receiver descriptions which follow are intended to illustrate the points just discussed. The various arrangements need not be followed slavishly by the constructor, providing principles of good design are not violated. For instance, any of the various band-spreading schemes already detailed may be substituted for the one in the particular set in which you are interested. If you prefer to use coils wound on forms other than those specified by all means do so, but at the same time remember that some modification of the coil sizes given will be necessary if the forms differ in diameter. Audio systems may be interchanged, likewise. A little common sense applied to most of the problems you may encounter will solve nearly all difficulties.

Tools

While it is possible to put a set together with the aid of only the proverbial jackknife, a few good tools of the proper sort will be found invaluable in saving time and helping to make a good job mechanically. The following list is typical of the tools which most amateurs consider adequate:

Soldering iron (preferably electric)
Large and small side-cutting pliers
Large and small screwdrivers
Hand drill stock with a few drills of different sizes (Nos. 11, 18 and 28 will be most useful)
File (not too large)
Knife (Boy-Scout kind)
Hammer
Vise (the small 4" size will do)
Steel rule (6" or 12")

With these tools it is possible to construct practically any of the apparatus ordinarily built at home. Others will be found useful at times, however. A small tap-holder, a die-holder and three or four taps and dies covering the 6-32, 8-32 and 10-32 sizes can be obtained from a hardware store at reasonable cost. With the dies you can thread brass rod and run over threads that become "bunged-up" on machine screws. With the taps you can

STANDARD RECEIVING TUBES

Type No.	Description	Filament or Heater		Plate Volts E_b	Neg. Grid Volts E_c	Screen Volts E_d	Screen Ma. I_d	Plate Ma. I_b	Plate Resistance r_p	Mutual Conductance Micromhos	Amp. Factor μ	Load Resistance Ohms	Power Output Watts (Audio)	Base Connections[1]				
		Volts E_f	Amps. I_f											1	5	6	7	Cap
30	Triode Det., Amp.	2.0	0.06	180	13.5			3.1	10,300	900	9.3			G				
32	S.G. R.F. Amp., Det.	2.0	0.06	180	3.0	67.5	0.4	1.7	1,200,000	650	780			S				G
34	Var.-μ S.G. Pentode	2.0	0.06	180	3.0	67.5	1.0	2.8	1,000,000	620	620			S				G
1A6	Pentagrid Converter[2]	2.0	0.06	180	3.0	67.5	2.4	1.3	500,000					G_3	G_2	G_1		G_4
19	Twin Amp. (Class B)	2.0	0.26	135	0			10–35				10,000	2.1	G				
31	Triode Power Amp.	2.0	0.13	180	30.0			12.3	3,600	1050	3.8	5,700	0.375	G	P	G		
33	Pentode Power Amp.	2.0	0.26	135	13.5	135	3.0	14.5	50,000	1450	70	7,000	0.7	G	S			
49	Dual-Grid Power Amp.[3]	2.0	0.12	180	0			4–35				12,000	3.5	G_1	G_2			
27	Triode Det., Amp.	2.5*	1.75	250	21.0			5.2	9,250	975	9.0			G	C			
56	Triode Det., Amp.	2.5*	1.0	250	13.5			5.0	9,500	1450	13.8			G	C			
24-A	S.G. R.F. Amp.	2.5*	1.75	250	3.0	90	1.7	4.0	600,000	1050	630			S	C			G
35	Var-μ S.G. R.F. Amp.	2.5*	1.75	250	3.0	90	2.5	6.5	400,000	1050	420			S	C			G
57	Pentode R.F. Amp.	2.5*	1.0	250	3.0	100	0.5	2.0	over 1.5 meg.	1225	1500			S	C	K		G
58	Var.-μ Pentode R.F. Amp.	2.5*	1.0	250	3.0	100	2.0	8.2	80,000	1600	1280			S	C	K		G
2A7	Pentagrid Converter[2]	2.5*	0.8	250	3.0	100	2.2	3.5	360,000					G_3	C	G_1	G_2	G_4
2A6	Duplex-Diode, High-μ Triode[4]	2.5*	0.8	250	1.35			0.4						D	C	D		G
2B7	Duplex-Diode, Pentode[5]	2.5*	0.8	250	3.0	125	2.3	9.0	650,000	1125	730			S	C	D	D	G
55	Duplex-Diode, Triode[4]	2.5*	1.0	250	20.0			8.0	7,500	1100	8.3	20,000	0.35	D	C	D		G
2A3	Triode Power Amp.	2.5	2.5	250	45.0			60.0	800	5250	4.2	2,500	3.5	G				
2A5	Pentode Power Amp.	2.5*	1.75	250	16.5	250	6.5	34.0	100,000	2200	220	7,000	3.0	S	C	G		
45	Triode Power Amp.	2.5	1.5	275	56.0			36.0	1,700	2050	3.5	4,600	2.0	G				
46	Dual-Grid Power Amp.[6]	2.5	1.75	250	33.0			22.0	2,380	2350	5.6	6,400	1.25	G_1	G_2			
47	Pentode Power Amp.	2.5	1.75	250	16.5	250	6.0	31.0	60,000	2500	150	7,000	2.7	G	S			
53	Twin Amp. (Class B)	2.5*	2.0	300	0			35–110				10,000	10.0	G	P	G	C	
59	Triple-Grid Power Amp.[7]	2.5*	2.0	250	28.0			26.0	2,400	2600	6.0	5,000	1.25	G_3	C	G_2	G_1	

Plate and screen ratings in this table are maximum.
* Indirectly-heated cathode.
[1] See tube-base layout diagram, Fig. 508. Pins 3 and 4 are always heater or filament connections; Pin 2 is always a plate. C, cathode; D, diode plate; G, control grid; G_1, G_2, G_3, G_4, grids in multi-grid multi-purpose tubes numbered in order from cathode; K, suppressor grid; P, plate; S, screen grid.
[5] Ratings refer to screen-grid section only.

Type No.	Description	Filament or Heater		Plate Volts E_b	Neg. Grid Volts E_c	Screen Volts E_d	Screen Ma. I_d	Plate Ma. I_b	Plate Resistance r_p	Mutual Conductance Micromhos	Amp. Factor μ	Load Resistance Ohms	Power Output Watts (Audio)	Base Connections[1]				
		Volts E_f	Amps. I_f											1	5	6	7	Cap
37	Triode Det., Amp.	6.3*	0.3	250	18.0			7.5	8,400	1100	9.2			G	C			
36	S.G. R.F. Amp.	6.3*	0.3	250	3.0	90	1.7	3.2	550,000	1080	595			S	C			G
39–44	Var.-μ Pentode R.F. Amp.	6.3*	0.3	250	3.0	90	1.4	5.8	1,000,000	1050	1050			S	C			G
77	S.G. R.F. Amp.	6.3*	0.3	250	3.0	100	0.6	2.3	1,500,000	1250	1500			S	C	K		G
78	Var.-μ S.G. R.F. Amp.	6.3*	0.3	250	3.0	125	3.0	10.5	600,000	1650	990			S	C	K		G
75	Duplex-Diode, High-μ Triode[3]	6.3*	0.3	250	1.35			0.4						D	C	D		G
85	Duplex-Diode, Triode[4]	6.3*	0.3	250	20.0			8.0	7,500	1100	8.3	20,000	0.35	D	C	D		G
6B7	Duplex-Diode, Pentode[5]	6.3*	0.3	250	3.0	125	2.3	9.0	650,000	1125	730			S	C	D	D	G
6F7	Triode, Pentode[6]	6.3*	0.3	250	10.0	100	0.6	2.8						S	C	G	P	G
6A7	Pentagrid Converter[7]	6.3*	0.3	250	3.0	100	2.2	3.5	360,000					G_3	C	G_1	G_2	G_4
6A4	Pentode Power Amp.[8]	6.3	0.3	180	12.0	180	3.9	22.0	45,500	2200	100	8,000	1.4	G	S			
38	Pentode Power Amp.	6.3*	0.3	250	25.0	250	3.8	22.0	100,000	1200	120	10,000	2.5	S	C			G
41	Pentode Power Amp.	6.3*	0.4	250	18.0	250	5.5	32.0	68,000	2200	150	7,600	3.4	S	C	G		
42	Pentode Power Amp.	6.3*	0.7	250	16.5	250	6.5	34.0	100,000	2200	220	7,000	3.0	S	C	G		
79	Twin Amp. (Class B)	6.3*	0.6	250	0			10–60				14,000	8.0	G	P	C		G
89	Triple-Grid Power Amp.[10]	6.3*	0.4	250	31.0			32.0	2,600	1800	4.7	5,500	0.9	G_2	C	G_3		G_1
864	Triode Amp.	1.1	0.25	135	9.0			3.5	12,700	645	8.2			G				
20	Triode Power Amp.	3.3	0.13	135	22.5			6.5	6,300	525	3.3	6,500	0.11	G				
22	S.G. R.F. Amp.	3.3	0.13	135	1.5	67.5	1.3	3.7	325,000	500	160			S				G
01-A	Triode Amp., Det.	5.0	0.25	135	9.0			3.0	10,000	800	8.0			G				
40	Triode Amp.	5.0	0.25	180	3.0			0.2	150,000	200	30			G				
112-A	Triode Amp., Det.	5.0	0.25	180	13.5			7.7	4,700	1800	8.5			G				
71-A	Triode Power Amp.	5.0	0.25	180	43.0			20.0	1,750	1700	3.0	4,800	0.79	G				
43	Pentode Power Amp.	25.0*	0.3	135	20.0	135	7.0	34.0	35,000	2300	80	4,000	2.0	S	C	G		
48	Tetrode Power Amp.	30.0*	0.4	125	22.5	100	9.0	50.0	10,000	2800	28	2,000	2.5	S	C	G		

[1] Ratings are for two tubes in Class B. [4] Triode ratings only. [5] Pentode ratings as screen-grid r.f. amplifier. [8] Class-A ratings. See Chapter Eight for Class-B ratings.
[7] Class-A triode ratings. Class-B ratings approximately the same as those of 46; Class-A pentode ratings approximately the same as those of 2A5. [6] Pentode unit as mixer.
[9] Also known as Type LA. [10] Class-A triode ratings. As pentode, maximum output is 3.4 watts; two 89's in Class B at 180 volts, 3.5 watts output.

thread the holes you drill so that they will take machine screws to hold the apparatus you wish to mount. A hacksaw, reamer, center-punch, scriber, tweezers, square and some other inexpensive tools are also desirable but not entirely necessary.

In building equipment for experimental purposes and for temporary use it is just as desirable

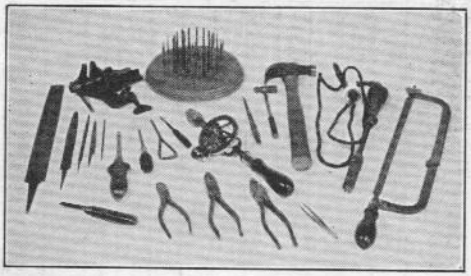

FIG. 509 — GOOD TOOLS CONTRIBUTE TO GOOD CONSTRUCTION

All those illustrated, although convenient, are not entirely necessary. Those suggested in the text are recommended as the basis for the constructor's equipment.

to use system in laying out the apparatus and in wiring up as when the more permanent panel job is built. Some square "breadboards," a bunch of General Radio plugs and jacks, Fahnestock clips, some scrap bakelite pieces for building terminal boards, angles for supports and an assortment of different sized brass machine screws, wood screws, nuts, and washers will make it easy to build up and try out new circuits. It is a good idea to keep some bus wire on hand, and various sized spools of magnet wire will prove useful in doing temporary wiring if you are an experimenter.

A table of drill sizes giving the proper numbered drill to use for passing a screw through a panel or for tapping to take a certain size of machine screw is included in the Appendix. Only the sizes most used in radio constructional work are given. Wood screws also come in various sizes and lengths. Usually the numbers correspond to the drill-size numbers, the diameter given being that of the screw just below the head. Wood screws are stocked by most hardware stores in lengths to the nearest quarter inch of what you want.

Soldering and Wiring

In wiring different pieces of apparatus a neatly soldered job will repay the builder in good appearance and reliable operation. Good connections may be made without solder, but a well-soldered job has low contact resistances. A soldered outfit works quietly and uniformly over long periods of time. Soldering is decidedly worthwhile when properly done.

Making soldered joints is a quite simple matter. A few points should be kept in mind for best results. A hot well-tinned soldering iron, clean, bright surfaces, and a *small* amount of rosin-core solder will do the trick. Tinning the parts to be soldered before completing a joint will be helpful.

Soldering flux keeps the clean surface from becoming oxidized when heat is applied. Acid fluxes or soldering pastes are especially to be avoided. They are good for mending tin pans and gutter pipes but cause corrosion of electrical connections. The melted "paste" can cause a set to operate poorly or to become inoperative by adding leakage paths across coils and condensers. Use lump or powdered rosin that can be obtained for a dime from any drug store, or buy "rosin-core" solder.

"Tinning" the soldering iron is done by filing the point bright and clean and rubbing it in hot solder with a little flux until the point is covered with clean solder. Scrape connections with a knife or file before soldering, to save time and make a joint good electrically and mechanically. The soldering iron must be re-tinned occasionally if it becomes overheated. It should always be used when very hot but not allowed to become red hot. A hot iron makes soldering easy.

Bus wiring is neat and effective. The wires are laid out in straight lines running straight back, horizontally and vertically. The corners are made square. Hold bus wires firmly with pliers while a little solder "runs" into the joint.

In receiver wiring, battery leads may be bunched to good advantage. Radio-frequency circuits should have the leads well spaced. Wires should cross at right angles when crossing is necessary. Connections between coils and condensers in radio-frequency circuits should be as short as possible. However, coils and condensers must not be jammed together too much as this increases the effective resistance and lowers the sensitivity. Leads a couple of inches long are permissible and will allow mounting the condenser out of the field of the coil.

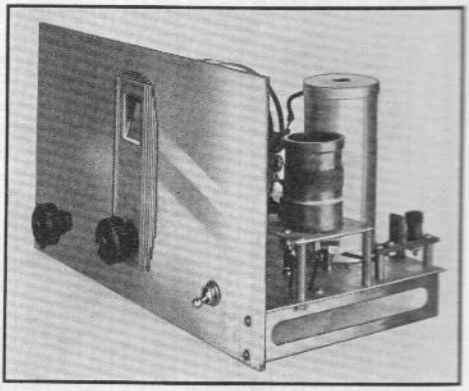

FIG. 510 — THE FRONT PANEL AND PART OF THE "CHASSIS" OF THE TWO-TUBE D.C.-A.C. RECEIVER

This photograph shows the detail of the coil and antenna condenser mountings. The detector tube shield is also visible.

A Two-Tube A.C.-D.C. Receiver

A simple receiver of sturdy construction that incorporates modern features is illustrated in Fig. 510. It uses a screen-grid regenerative detector and one stage of audio amplification, being intended for headset output. The model pictured happens to be fitted for operation with 2½-volt a.c. filament supply but is also adaptable to operation from 6-volt a.c. or d.c., or 2-volt battery supply, as described in the circuit diagrams of Figs. 511 and 514. Somewhat better results will be obtained with the 2½- or 6-volt tubes than with the 2-volt types, however. Plug-in coils are used and the band-spread system of Fig. 503-C is employed. The regeneration control is of the type illustrated in Fig. 504-B.

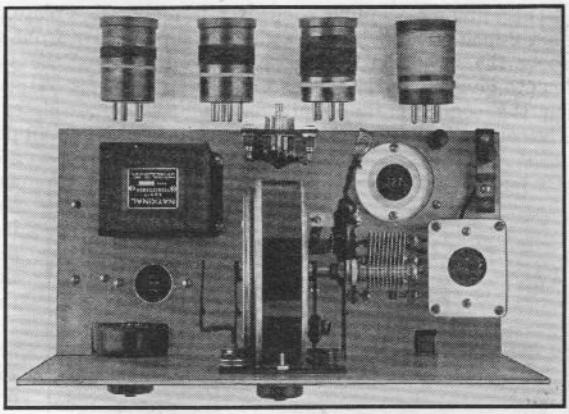

FIG. 512 — THE TOP OF THE SUB-PANEL

The audio coupler, audio amplifier tube socket and regeneration-control resistor are to the left of the drum dial. Connections are brought out to the cable socket to the rear of the dial. Tip-jacks for the 'phones are mounted on this socket. This photo also shows the method of mounting the tuning condenser, grid condenser and leak, and shows the coil socket and antenna condenser mountings from another angle. The ground binding post is mounted on the sub-panel between the detector tube socket and the antenna condenser.

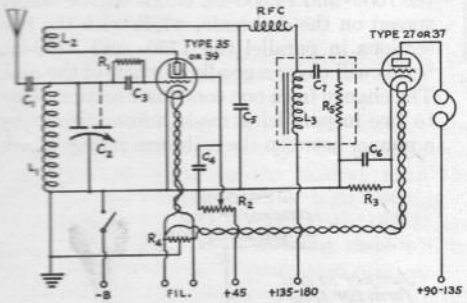

FIG. 511 — CIRCUIT OF THE TWO-TUBE RECEIVER FOR HEATER-TYPE TUBES

As alternatives to the tubes indicated, for 2.5-volt a.c. heater operation a Type 58 may be used for the detector, with a 6-prong socket replacing the 5-prong used for the 35 and with the suppressor of the 58 (No. 6 pin) connected to the cathode; also, a 56 may be used to replace the 27 without changing the socket. For 6-volt d.c. operation a Type 78, with a 6-prong socket connected as for the 58, can be used in the detector with a 37 in the audio stage. The filament center-tap resistor R_4 should be omitted for d.c. operation.

C_1 — Antenna coupling condenser; see text for details.
C_2 — Split stator condenser; see text.
C_3 — 100 μμfd.
C_4 — .5μfd.
C_5 — 200 μμfd.
C_6 — 1.0 μfd.
R_1 — 10 megohms.
R_2 — 100,000-ohm variable resistor.
R_3 — 2000 ohms.
R_4 — 20-ohm center-tapped resistor (not required if d.c. tubes are used).
RFC — Receiver-type r.f. choke.
L_3, C_7, R_5 — National Screen-Grid Detector Coupler, Type S-101. If a home-made coupling is assembled, C_7 should be about .006μfd. and R_5, 2-4 megohms. See text for details of L_3.

Coil Data

Band	L_1	L_2
1750	70 turns No. 32 s.c.c.	10 turns No. 32 s.c.c.
3500	37 " " 22 s.c.c.	6 " " 30 "
7000	19 " " " "	4 " " " "
14,000	8 " " " "	4 " " " "

All coils are close-wound except the 14,000-kc. grid coil. The spacing between turns on this coil is adjusted until the band is covered. Spacing is approximately half the diameter of the wire.

The panel is a piece of ⅛-inch sheet aluminum, 7 inches high and 12 inches wide. On it are mounted the drum dial which controls the tuning condenser, the regeneration control resistor, and the "B" cut-off switch, as shown in 510 and 512. The remaining apparatus is mounted on the shelf or "sub-panel," which is also sheet aluminum, 12 inches wide and 6 inches deep. The sub-panel mounting brackets are one inch high.

Three five-prong sockets are required, one for the plug-in coils and two for the tubes; the variety used in this particular set are sub-panel sockets of the type widely used by broadcast-receiver manufacturers. It is not necessary to use the same style, of course, although they lend themselves nicely to sub-panel wiring and are inconspicuous.

The tuning condenser is a National Type SE-100 with several plates removed for band-spreading. The drum dial is a National Type HS, which is the projector dial with special mounting brackets for the Type SE condenser. To the right of the condenser, as shown in the top view of the receiver, Fig. 512, is the mounting for the coil socket, and just behind the latter is the mounting for the antenna coupling condenser and the antenna binding post. The reason for these two special mountings is obvious when it is remembered that the sub-panel is metal. The mounting for the coil socket is made from a piece of 1/16th-inch aluminum 2 inches by 2½ inches, supported at each corner by brass sleeves 1⅜" long bolted to the sub-panel.

The antenna coupling condenser is mounted on a 2-inch strip of bakelite which is supported above the sub-panel by two spacers sufficiently long to give ample clearance for the screws holding the condenser and antenna binding post. The condenser itself consists of two strips of thin brass about a half inch wide, bent to face each other about ⅛ inch apart as shown in the photograph.

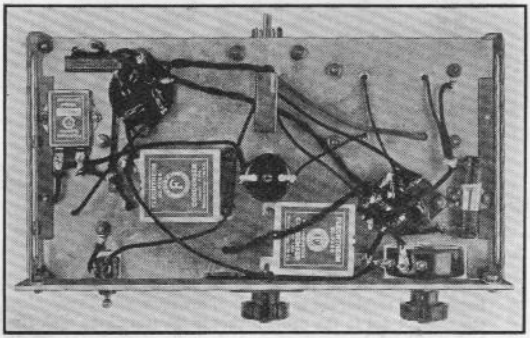

FIG. 513 — UNDER THE SUB-PANEL

The center-tapped resistor for the heater leads is mounted directly underneath the ground binding post. The small condenser to the left is the plate by-pass condenser; the one below the detector tube socket is the screen-grid by-pass condenser. The r.f. choke is in the center. The cathode resistor for the audio tube is at the extreme right, held in place by a home-made bracket. The by-pass condenser across the resistor is mounted between the r.f. choke and the front panel. The metal piece behind the r.f. choke is a bracket which rests on the table and serves as a mechanical support for the sub-panel.

To spread the various bands satisfactorily the capacity ratio of the tuning condenser is changed for each band so that stations will not be unduly crowded.

The type of tuning condenser used is a particularly easy one to alter for band spreading, since the stationary plates can be removed without difficulty. The nuts holding the stationary plate assembly to the insulating strip on the front of the condenser should be removed; then the two screws holding the rear strip to the frame should be taken out and the stationary plates can be lifted out. The condenser as revamped for this receiver has two stationary sections insulated from each other. One consists of one plate and the other of two, each section being mounted on one of the insulating strips. Three-quarter inch 6-32 machine screws are used to hold the two stator sections in place. Fig. 516 shows clearly how these changes are made.

The connections between the condenser and the coil socket are made as shown in Fig. 515. The single plate alone may be used, or the two sections may be connected in parallel. With the single-plate stator only, the 7000- and 14,000-kc. bands will be amply spread on the dial scale, while with the two sections in parallel the 1750- and 3500-kc. bands will cover a goodly portion of the dial. The change from one condenser section alone to two in parallel is made automatically by a jumper between the coil-form prongs which connect to the two stator sections of the tuning condenser when the coil is placed in the socket.

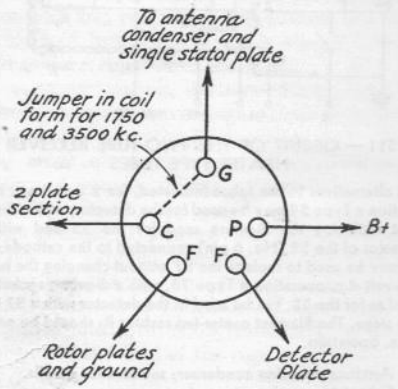

FIG. 515 — COIL FORM AND SOCKET CONNECTIONS FOR THE TWO-TUBE RECEIVER

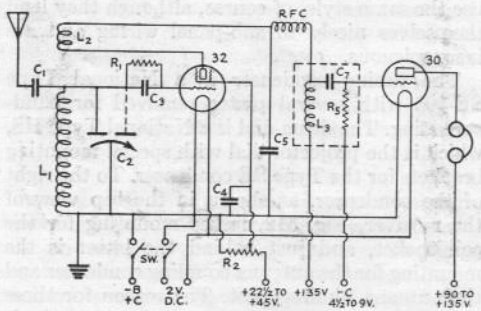

FIG. 514 — DIAGRAM OF TWO-TUBE RECEIVER FOR 2-VOLT D.C. OPERATION

The circuit is the same as in Fig. 511, except that 4-prong sockets are used and a d.p.s.t. switch is included to cut off the B-battery and filament supply circuits simultaneously. This is necessary to prevent B-battery drain when the receiver is inoperative.

Other details of the arrangement of the parts and of the wiring can be followed in an examination of the illustrations. It will be noted that a Yaxley cable socket is used in place of binding posts for external leads and that all wiring is made with flexible "hook-up" wire, the leads running directly from one point to another.

In this receiver the coils are wound on manufactured five-prong coil formers. Specifications for the windings are given, but it may be necessary to make slight changes in them in order to obtain the best possible performance. Since the antenna will have some effect on the tuning of the detector circuit, it may be found that the bands will not be centered on the tuning dial unless a

few turns are added to or subtracted from the numbers specified for the grid coils. It is particularly important that the tickler windings be adjusted so that the detector oscillates with approximately 22 volts on the screen-grid. To

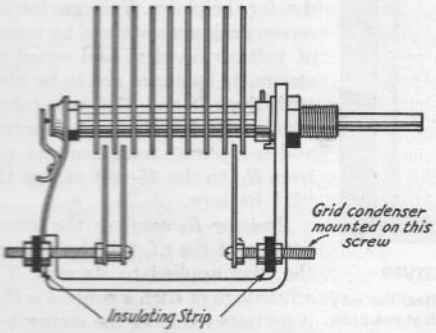

FIG. 516 — HOW THE TUNING CONDENSER IS REMODELLED FOR THE TWO-TUBE RECEIVER

accomplish this it is helpful to connect the screen-grid lead temporarily to a 22½-volt tapping, then adjusting the ticklers until the detector just oscillates at the "high" setting of the regeneration control, R_2. With the screen lead back on the 45-volt tapping there will be plenty of range for the regeneration control.

Instead of using an audio transformer with the primary and secondary connected in series as a coupling impedance in the detector plate circuit, as might be done, a special coupler made for the purpose is used in this set. The audio transformer stunt may be used instead, of course.

There should be no hum in the receiver with a.c. tubes and an a.c. filament supply. If filament hum is encountered make certain that the center-tap resistor, R_4, is connected properly and that the receiver is connected to a good ground. A cold water pipe is best. If this does not cure it, try other tubes. An otherwise good tube may have a bad hum, especially when used as a regenerative detector. There will be no hum, of course, with d.c. tubes and a storage battery filament supply.

Either batteries or a power pack may be used for the plate and screen-grid voltages. Many "B" substitutes, while entirely adequate for broadcast receivers or audio amplifiers, are unsatisfactory on short-wave regenerative receivers because their output voltage is not constant, making the received signals sound unsteady or causing tunable hums. Chapter Ten goes into this subject in more detail. If batteries are used the switch in the minus "B" lead should be opened when the receiver is not in operation, to cut off the current which otherwise would be drained through R_2. This receiver will work well with 135 volts of "B" batteries, and since the total current is only about 5 or 6 milliamperes the batteries will last a long time.

A Three-Tube Receiver

The progressive amateur is rarely content to operate a receiver not fitted with at least one stage of radio-frequency amplification. The increase in sensitivity and the general improvement in performance made possible by a stage of r.f. amplification is usually well worth the additional apparatus and the added construction.

The three-tube receiver illustrated and diagrammed in Fig. 519 has a tuned r.f. stage with controllable sensitivity. The circuit arrangement differs a little from those previously described, but the operating principles are the same. The band-spreading system will be recognized as the first of those outlined early in this chapter. It is used in this set because it is one of the easiest systems to get working when the tuning of two stages is to be ganged, and because the relatively large capacity in the tuned circuits makes the detector oscillate more stably and thus prevents the signals from wavering should the "B" supply voltage change slightly.

The panel is of ⅛-inch aluminum and measures 7 by 14 inches. The sub-base is made of a single piece of $\frac{3}{32}$-inch aluminum with the corners cut

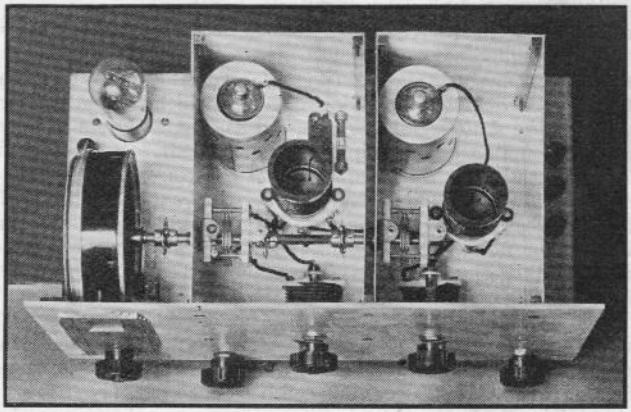

FIG. 517 — PLAN VIEW OF THE THREE-TUBE AUTODYNE WITH SHIELD COVER REMOVED

The panel view of this receiver appears at the beginning of the chapter. The detector stage is next to the drum dial. The ganged tuning condensers are mounted on the left-hand wall of each shield. The Isolantite coil sockets are mounted on small pieces of brass tubing which lifts them far enough above the base to prevent grounding of the contacts. The detector grid condenser and leak are just behind the coil in the detector compartment. The tubes, also mounted in sub-panel sockets, have individual shields.

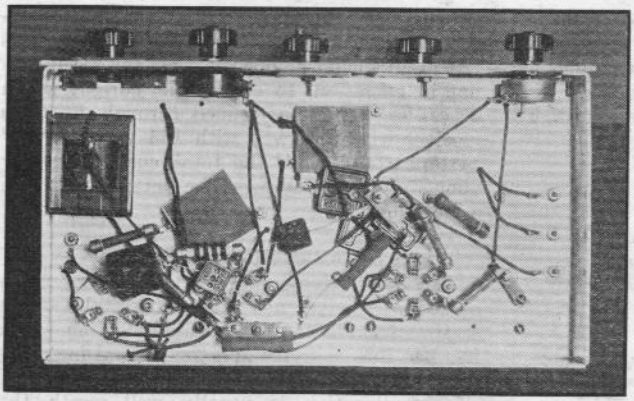

FIG. 518 — UNDER THE BASE OF THE THREE-TUBE RECEIVER

Resistors, by-pass condensers, chokes, all placed where most convenient. The only thing to keep in mind in this sub-base wiring is to make all the r.f. grounds at one point on the chassis. The audio coupler is mounted on the side at the left.

out and edges bent down in a vise so that the top surface is 13½ by 7½ inches and the vertical sides are two inches high. The two shield boxes are made of 1/16-inch aluminum, each measuring 4¾ inches high, 4¼ inches wide and 7 inches deep. The panel constitutes the front of both boxes. The pieces making up the sides of the boxes are fastened together by being screwed to vertical pieces of ¼-inch square brass rod which have been drilled and tapped to take small machine screws at appropriate points. Similar rods also are used to fasten the boxes to the panel.

It is important, in building up the chassis, to make certain that good contact is made between all metal parts. Loose panels in the shield boxes will result not only in poor shielding but will undoubtedly be the source of many noises.

The tuning condensers are Hammarlund midgets, mounted as shown in Fig. 517. To gang the two condensers the spring contacts which wipe on the shaft should be removed so that a flexible coupling can be slipped over the shaft. The connection to the rotor plates of the condenser so altered should be made through the *front* bearing when this is done, because the rear bearing will be noisy. The condensers and dial are connected together by means of pieces of quarter-inch shafting and small flexible couplings.

The detector circuit is designed to permit the use of 5-prong coil forms. Only three terminals are needed for the oscillating circuit, the other two being available for the coupling coil from the r.f. stage. The tickler in this circuit comprises the portion of L_4 between cathode and ground, and is smaller than the tickler of more usual regenerative circuits.

A small audio transformer is used to couple the detector to the audio amplifier. A coupler such as the one used in the two-tube a.c. receiver can be substituted, provided changes are made in the mechanical arrangement of the set so it can be fitted in.

The wiring diagram, Fig. 519, is for operation from an a.c. power pack which will deliver 2.5 volts a.c. for the filaments and 200 volts d.c. for the plates. Voltages for the screen grids are obtained by means of voltage dividers and series resistors. If batteries are to be used with Type 78 and 37 6-volt tubes, resistors R_5 and R_6 may be omitted and a separate lead brought out from R_{10} to the 45-volt tap on the "B" battery.

Resistor R_3 controls the amplification of the r.f. tube by varying the bias applied to its grid. The advantage of such a control is that it permits reducing the strength of strong signals and thus prevents the detector from "blocking" or "pulling in." A strong signal will occupy much more space on the dial than a weak one unless its strength can be reduced. The sensitivity control does this and thereby greatly increases the *effective* selectivity of the receiver.

The antenna input has been arranged so that a doublet antenna can be used with the receiver (see Chapter Twelve). With an ordinary antenna and ground, one of the antenna posts should be connected to the ground post to complete the circuit.

Should the set not work right at the first trial, check over the wiring and apply the tests outlined later in this chapter. These tests also apply to the two-tube a.c.-d.c. receiver previously described.

A Single-Signal Superheterodyne

In c.w. reception with the autodyne receivers just described identical beat notes are obtainable from two signals of different frequency, one beat-note frequency higher than the local oscillator (detector) frequency and the other beat-note lower. Thus a considerable portion of interference results from undesired signals that are actually several kilocycles removed from the desired signal frequency, even though their beat notes may be identical with desired signals. (*QST*, June, 1932). This type of interference in c.w. reception, together with much noise and other interference to c.w. signals and 'phone signals as well, is eliminated in the single-signal type superheterodyne. This type receiver resembles generally the standard type superheterodyne, whose principles have been outlined in Chapter Four, but has in addition to the conventional tuned i.f. circuits a circuit in which extremely high selectivity is obtained either by means of a quartz crystal (piezo-electric) filter (*QST*, August and September, 1932); or by regeneration (*QST*, April, 1933). A separate beating oscillator, tuned to a frequency suitably

different from the i.f. peak, gives the audio beat note for c.w. reception. As originated in the A.R.R.L. laboratory, receivers of the single-signal type have selectivity controllable over a considerable range so that the degree of selectivity suitable for different types of signals, c.w. and 'phone, is readily obtainable in operation.

An illustration of the regenerative type s.s. receiver, recommended for amateur construction, is the model diagrammed in Fig. 522 and shown in the accompanying photographs. This receiver is actually a conversion of the three-tube autodyne previously described and uses most of the parts of the regenerative receiver. In the conversion, the r.f. stage becomes the superhet's first detector; the regenerative detector becomes the high-frequency oscillator; and the audio amplifier tube is replaced by a power-type pentode second detector. The i.f. amplifier and c.w. beat oscillator occupy the chassis extension at the rear, as identified in the illustrative figures. The high-frequency tuning system remains unchanged except for minor modifications in the coils and wiring.

Tracing the operation briefly, the incoming signal is "mixed" with the signal from the high-frequency oscillator, which is capacitively coupled to the first detector grid, so as to produce a signal of 500-kc. intermediate frequency. The h.f. oscillator is therefore always tuned 500 kc. different from the received signal frequency, usually 500 kc. higher. The 500-kc. i.f. signal produced is then amplified in the high-gain high-selectivity i.f. stage and passed to the second detector. For 'phone signals detection occurs in normal fashion, while for c.w. telegraph reception the separate beat oscillator is used to heterodyne the i.f. signal in the second detector to produce the audio beat note, the second oscillator being tuned approximately 1000 cycles off the i.f. peak frequency. The sensitivity of the first detector is controlled by the variable cathode resistor R_3 while the i.f. selectivity is controlled by the regeneration resistor, R_9. This resistor, in series with the condenser C_8, is effectively across the tickler (feed-back) coil L_7 and operates to vary the regeneration by r.f. short-circuiting action. The 2A5 power pentode type tube used as a second detector provides audio output comparable to that obtained with the usual detector and one audio stage, and makes additional audio amplification unnecessary for usual purposes.

In the mechanical assembly, an additional hole is drilled in the front panel for the ¼-inch shaft of the i.f. regeneration control, midway between the other two controls. Of the latter, the right-hand one remains the cathode resistor control while the left-hand one becomes the control

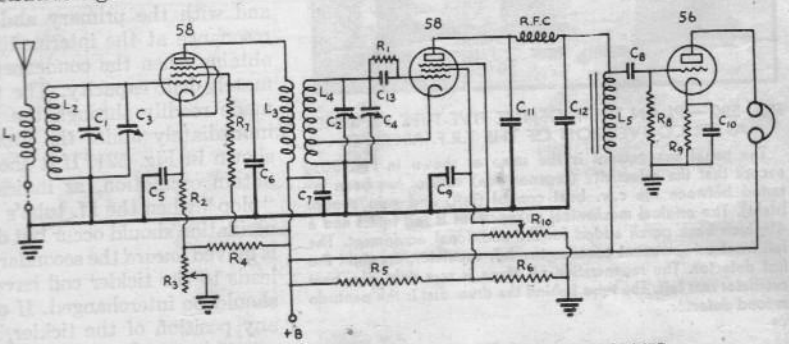

FIG. 519 CIRCUIT DIAGRAM OF THE THREE-TUBE RECEIVER

The tube filaments (heaters) and the dial light are wired in parallel. The tubes indicated on the diagram, are for 2.5-volt a.c. operation. The 58's would be replaced by 78's, the 56 by a 37 and a 6-volt dial light should be used for 6-volt d.c. operation. With battery B supply resistors R_5 and R_6 should be omitted, and the positive terminal of the regeneration control R_{10} should be connected to the plus-45-volt battery tap; also, a d.p.s.t. switch should be included to cut off both sides of the B supply when the receiver is not in use, in addition to a switch in the filament circuit. The negative-B connection is made to the chassis (ground). Heavy lines indicate "ground" connections which should be made to a single common point on the chassis. Power-pack design for a.c. operation is given in Chapter Ten.

C_1, $_2$ — 35-$\mu\mu$fd midget condensers (Hammarlund MC-35-S). See text.
C_3, $_4$ — 100-$\mu\mu$fd. midget condensers (Hammarlund MC-100-S).
C_5, $_6$, $_7$, $_8$ — .01-μfd. mica condensers.
C_9, $_{10}$ — 1-μfd. non-inductive paper condeners.
C_{11}, $_{12}$ — 100-$\mu\mu$fd. fixed mica condeners.
C_{13} — 250-$\mu\mu$fd. mica condenser.
R_1 — 5-megohm resistor.
R_2 — 250 ohms, 2 watt.
R_3 — 10,000-ohm wire-wound potentiometer, tapered.
R_4 — 50,000 ohms, 2 watt.
R_5 — 14,000 ohms, wire-wound, 5 watt.
R_6 — 5000 ohms, wire-wound, 5 watt.
R_7 — 100,000 ohms, 1 watt.
R_8 — 1 megohm.
R_9 — 2000 ohms, 1 watt.
R_{10} — 50,000-ohm potentiometer.

Coil Data

L_1, L_2 on same form; L_3, L_4 ditto.

Band	L_1	L_2	L_3	L_4
1750	10	55	30	55 tapped at 3rd turn
3500	6	28	20	28 " " 1st "
7000	5	11	9	11 " " ½ "
14,000	3	5	5	5 " " ¼ "

All primaries (L_1 and L_3) are wound with No. 36 d.s.c. wire. The 3500-kc. grid coils are wound with No. 20 d.c.c.; 1750-kc. grid coils with No. 28 d.c.c.; both close-wound. The 7000- and 14,000-kc. grid coils are wound with No. 18 enamelled wirespaced to occupy a length of 1¼ inches. Taps are from the ground end of detector coils. National 5-prong coil forms (diameter 1½ inches) are used. Spacing between coils on form is approximately ⅛ inch.

for the c.w. beat oscillator frequency adjustment. As shown in the bottom view, ¼-inch Bakelite shafts with flexible couplings are used for C_6 and R_9. The rear chassis extension measures 13½ inches by 4½ inches by 2 inches deep. It is fastened to the original base with pieces of the

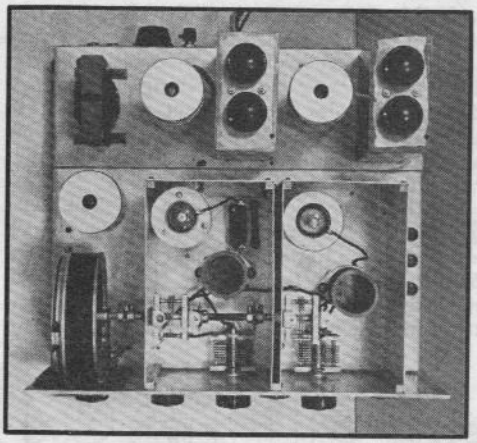

FIG. 520 — PLAN VIEW OF THE FIVE-TUBE SUPERHET AFTER CONVERSION OF THE T.R.F. RECEIVER

The panel arrangement is the same as shown in Fig. 501, except that the selectivity (regeneration) control has been inserted between the c.w. beat control (left) and gain control (right). The original mechanical arrangement is left intact and a 4½-inch back porch added for the additional equipment. The left front compartment contains the h.f. oscillator, the right the first detector. The regenerative r.f. stage is rear right, the beat oscillator rear left. The tube behind the drum dial is the pentode second detector.

quarter-inch square brass rod drilled and tapped for 6–32 screws, at the front corners and near the top-center. On the base are mounted the i.f. transformers, the i.f. and beat-oscillator subpanel tube sockets, and the output transformer, as shown in the plan view of Fig. 520.

The i.f. transformers in this particular case are home-made. Air-type (midget) condensers are used for tuning in preference to less stable compression-type mica condensers. The i.f. transformer shields measure 4 inches by 2 inches by 4 inches high and are made of thin copper sheet, with the joints soldered. The inner assembly is as shown in the illustration of the second i.f. transformer, Fig. 523. The first i.f. transformer is similar except that it has, in addition, the tickler coil L_7. The two 100-$\mu\mu$fd. Hammarlund midget condensers are mounted on a 3½- by 1¾-inch strip of 3/16-inch bakelite which, in turn, is supported from the top of the can by 6–32 screws through spacing bushings that prevent the condenser bearings from shorting to the shield. Holes through the shield for the condenser shafts are large enough so that they do not short either. The transformer coils, on a 3-inch length of ½-inch wood dowel, are supported from the condensers by strips of 1/16- by ½-inch fiber screwed to the condenser frames and bent to hold the coil assembly clear of the other components and the base, as shown in Fig. 523. The universal-wound r.f. choke, RFC_2, is mounted on one of these supports.

The primary and secondary i.f. coils are of the "diamond weave" (universal) type and are each of 1-millihenry inductance. They are mounted approximately 1 inch apart. The tickler coil of the first transformer is a 20-microhenry coil of the same type, mounted relative to the other coils and with leads brought out as shown in Fig. 524. The coils shown were obtained from the F. W. Sickles Co., Springfield, Mass. With the coils arranged as shown, the proper location of the tickler is determined by experiment, with the transformer connected in the tube circuit. The tickler is moved on the dowel form until a position is found where oscillation just starts with the regeneration control resistor at maximum and with the primary and secondary tuned to resonance at the intermediate frequency, which obtains when the condensers C_5 are at approximately half capacity. The tickler adjustment is made readily through the slot cut in the base immediately under the first i.f. transformer, as shown in Fig. 521. If it should be impossible to obtain oscillation, as indicated by the familiar "plop" when the i.f. tube's grid is touched, or if oscillation should occur but decrease as the tickler is moved *toward* the secondary, it is likely that the leads to the tickler coil have been reversed, and should be interchanged. If oscillation persists at any position of the tickler, it's turns should be

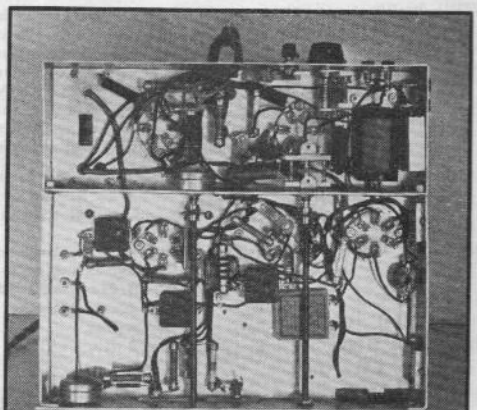

FIG. 521 — THE UNDERSIDE OF THE CHASSIS

Wiring and components are placed as convenient. A hole underneath the first i.f. transformer gives convenient access for adjusting the tickler position. The regeneration control resistor (near center) and beat-note control condenser are in the rear compartment, with ¼-inch bakelite shaft extensions to the panel knobs.

reduced in number or provision made to place it further from the secondary, as by using a longer dowel form.

Although it was not found necessary to enclose the c.w. beat oscillator circuit in a shield in the model shown, it may be advisable to do so according to the dash-line indicated in Fig. 522, the circuit diagram of the receiver. The other shielding indicated in this diagram is used, including the shielding of certain leads. This shielding is flexible copper braid (Belden) over "spaghetti" tubing. The wiring of the receiver is straightforward, the physical arrangement following closely the schematic arrangement of Fig. 522. The placement of bypass condensers, resistors and chokes is not especially critical but they should be located approximately in conformity with their positions in the schematic diagram, with connecting leads as short and direct as possible. All circuit connections indicated as "grounded" should be inter-connected by a copper wire soldered to each "ground" point, to eliminate possibility of poor connections through the aluminum shielding.

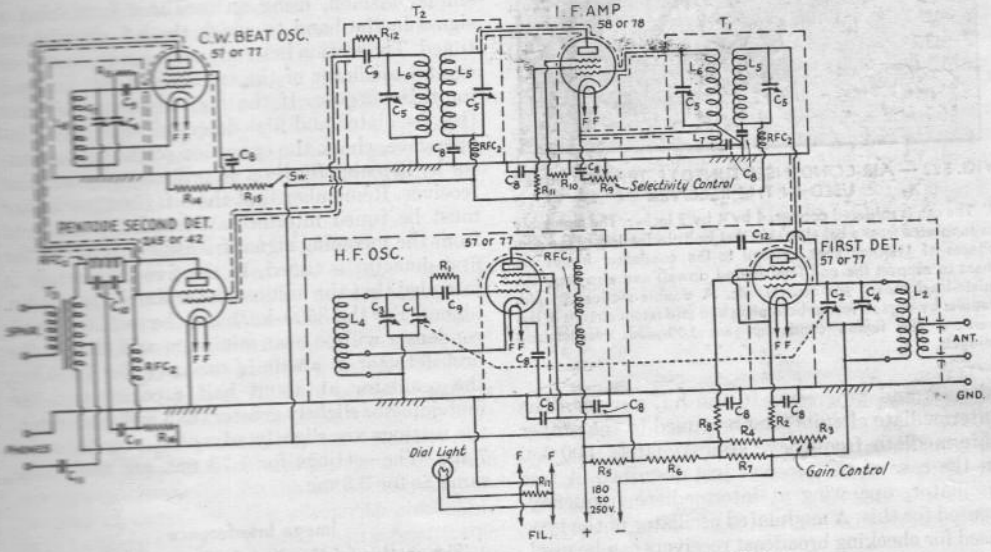

FIG. 522 — COMPLETE CIRCUIT OF THE FIVE-TUBE S. S. SUPERHET

Most of the components are unchanged from the three-tube receiver previously described, which should be studied for the additional constructional data. The original r.f. amplifier coils are used in the first detector and the original detector coils are used in the h.f. oscillator, with change in the cathode taps of the latter as noted below. See Fig. 519 for coil data.

L_1 and L_2 — Antenna and grid coils of first detector unchanged.
L_3 — Not used. Leave disconnected from circuit.
L_4 — Unchanged except that cathode tap is placed 1/4 to 1/3 of total turns from ground end. (Not critical.)
L_5 and L_6 — See text.
L_7 — See text.
L_8 — Beat oscillator inductor. 140 turns of No. 30 d.s.c. or equivalent on 1 1/2-inch diameter form. Length of winding 1 7/8 in. Tapped 30 turns from ground end.
C_1 and C_2 — Ganged tuning condensers, 35-$\mu\mu$fd. midgets. (Unchanged.)
C_3, C_4 — Tank padding condensers, 100-$\mu\mu$fd. midgets. (Unchanged.)
C_5 — I.f. tuning condensers, 100-$\mu\mu$fd. midgets.
C_6 — Beat oscillator tuning condenser, 20- or 25-$\mu\mu$fd. midget.
C_7 — Beat oscillator tank padding condenser, 200-$\mu\mu$fd. midget variable or 100-$\mu\mu$fd. midget in parallel with 100-$\mu\mu$fd. fixed mica.
C_8 — Non-inductive r.f. by-pass condensers, 0.005-μfd. or larger (paper or mica).
C_9 — 250-$\mu\mu$fd. mica grid condenser.
C_{10} — 250-$\mu\mu$fd. plate by-pass condensers.
C_{11} — 1-μfd. audio by-pass and coupling condensers.
C_{12} — H.f. oscillator coupling condenser, same as C_1 of Fig. 511.
R_1 — 50,000-ohm 1-watt oscillator grid leak.
R_2 — First detector cathode resistor, 5000-ohm 1-watt.
R_3 — 2000-ohm variable resistor, "left-hand" taper preferred.
R_4 — 100,000-ohm 1-watt.
R_5 — 10,000-ohm 5-watt.
R_6 — 7000-ohm 2-watt.
R_7 — 3000-ohm 2-watt.
R_8 — 50,000-ohm 1-watt.
R_9 — 2000-ohm variable resistor, preferably non-inductive type with "left-hand" taper.
R_{10} — I.f. amplifier cathode resistor, 300-ohm 1-watt.
R_{11} — 50,000-ohm 1-watt.
R_{12} — Detector grid leak, 1-megohm 1/2-watt.
R_{13} — Beat osc. leak, 50,000-ohm 1-watt.
R_{14} — 2500-ohm 2-watt.
R_{15} — 10,000-ohm. 5-watt.
R_{16} — 25,000-ohm 5-watt.
R_{17} — 20-ohm center-tap resistor for 2.5-volt tubes, 100-ohm for 6-volt tubes. Omitted with d.c. filament supply.
T_1 and T_2 — 525-kc. i.f. transformers. See text.
T_3 — Audio output transformer, push-pull "replacement" type.
RFC_1 — Sectionalized type short-wave choke, 3-to 8-millihenry. One with universal-wound sections preferred. (National No. 100 or equivalent.)
RFC_2 — 40- to 60-millihenry broadcast-band type r.f. chokes. Single-section universal-wound type satisfactory.

Dash lines indicate shielding. Shading indicates chassis. "Ground" points are bonded with copper wire, in addition to connection through chassis.

Alignment and Checking of the Superhet

The tuning and checking of operation of the various sections of any superhet receiver is best accomplished by a logical procedure. With the audio circuits operating properly, as indicated by strong clicks in the output when the detector grid is touched, this procedure starts with the i.f.

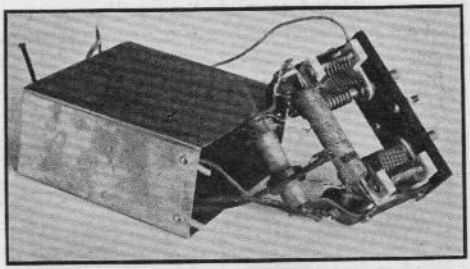

FIG. 523 — AIR-CONDENSER TUNED I.F. TRANSFORMER USED IN THE RECEIVER

The can is soldered copper, 4 by 4 by 2 inches. The asssembly is supported from a bakelite strip that bolts to the top of the can. Pieces of 1/16-inch fiber screwed to the condenser frames are bent to support the coil form (wood dowel) and also carry the plate-feed choke, grid resistor, etc. A double-section .01-μfd. tubular by-pass serves for both plate and grid return circuits in this version. The tuning condensers are 100-μμfd. Hammarlund midgets.

circuits and progresses to the h.f. circuits. The intermediate circuits are first tuned to the proper intermediate frequency, approximately 500 kc. in the case of the receiver just described. A test oscillator, operating at intermediate frequency, is used for this. A modulated oscillator of the type used for checking broadcast receivers can be used, or an unmodulated oscillator having exactly the same circuit as the c.w. beat oscillator of the receiver can be made up. With the unmodulated oscillator a d.c. milliammeter connected in a plate lead of the second detector is best as a visual resonance indicator. In the five-tube s.s. receiver a 0–50 milliammeter should be connected in the plus-B lead to the lower terminal of the output transformer primary. Since the detector is of the grid-leak type, the current will dip toward zero and minimum current will indicate resonance. For detectors having cathode-resistor self-bias, a 0–1 ma. meter can be used, which will indicate resonance by maximum current reading.

The frequency of the test oscillator can be checked by beating its second harmonic against the carrier of a broadcast station tuned in on a broadcast receiver set at 1000 kc. or thereabouts. In aligning the i.f. circuits, the test oscillator is first coupled loosely to the grid of the i.f. tube preceding the second detector (the second i.f. stage in a two-stage intermediate amplifier) by means of an insulated wire hooked around the grid cap. The primary and secondary of the *last* i.f. transformer are then adjusted to resonance. The coupling is next transferred to the grid of the next preceding tube (the first detector, in the s.s. five-tuber, or the first i.f. in a two-stage i.f. amplifier), and the second-last i.f. transformer is adjusted. In the regenerative i.f. amplifier this adjustment should be made with the regeneration control near minimum. If there is a third i.f. transformer, the same procedure applies to it; the test oscillator is always coupled to the grid of the tube preceding the transformer under adjustment. The c.w. beat oscillator should be "off" while the i.f. circuits are being aligned.

The high-frequency circuits are adjusted in similar fashion, using an oscillator furnishing a signal in the band to which the h.f. circuits are tuned. The station heterodyne frequency meter or crystal oscillator of the transmitter can be used for this purpose. If the high-frequency circuits (h.f. oscillator and first detector) seem to be inoperative, check the operation of the h.f. oscillator by listening for it on an ordinary regenerative receiver. Remember that the h.f. (first) oscillator must be tuned intermediate-frequency different from the incoming signal frequency to which the first detector is tuned. In the five-tube set, it is intended that the first oscillator should be 500-kc. higher. For the 3500–kc. band the oscillator tank condenser will be near minimum and that of the first detector at about ¼ capacity; for 7000 kc., the oscillator at about half capacity and the first detector slightly greater than half; for 14 mc., the settings are slightly advanced over those for 7 mc. The settings for 1.75 mc. are nearly the same as for 3.5 mc.

Image Interference

The setting of the first detector tank (padding) condenser is especially important in the minimizing of high-frequency image interference, a type of interference peculiar to superhet receivers.

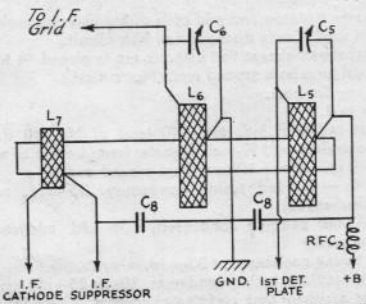

FIG. 524 — HOW THE COILS ARE ASSEMBLED IN THE REGENERATIVE I.F. TRANSFORMER

With all three wound in the same direction, the correct polarity of the tickler is obtained with the connections indicated. The 1-millihenry primary and secondary coils, L_5 and L_6, are spaced approximately 1 inch between centers. The 20-micro-henry tickler, L_7, is adjacent to the secondary and its proper position is determined by the procedure described in the text. All three coils are of the "universal" type made by the F. W. Sickles Co., Springfiled, Mass. Coils of different size and type might necessitate modification of the tickler specifications.

This interference results when signals twice intermediate frequency removed from the desired signal get through to beat with the high-frequency oscillator signal in the first detector and occurs because there is insufficient selectivity ahead of the first detector to discriminate against them. It is aggravated when the first detector circuit is off-tune for the desired signal frequency. The first detector therefore should be tuned as precisely as possible to the desired-signal frequency. For further improvement in signal-image response ratio, a tuned r.f. stage, exactly like that shown earlier in the chapter and having a tuned circuit identical with that of the first detector, can be added ahead of the first detector. This also will improve the sensitivity of the receiver. Images also can be reduced by using a simple wave-trap, of the type described in Chapter Eleven, tuned to the image frequency (1000 kc. above signal frequency) and connected in the antenna lead as closely as possible to the receiver's antenna terminal. (*QST*, December, 1933).

Quartz Crystal I. F. Filters

As has been mentioned previously, high i.f. selectivity can be obtained by the use of a quartz crystal filter and such filters are used in a number of s.s. receivers, two commercially manufactured types of which are shown later in this chapter. When connected in a suitable series circuit, a quartz crystal having a resonant frequency corresponding to the receiver's intermediate frequency is capable of several hundred times the selectivity obtainable in the usual transformer-coupled i.f. amplifier. The selectivity obtainable is, in fact, considerably greater than is practicable for some types of communication, especially 'phone, unless means for modifying it are provided. Such provision is made in the variable-selectivity filter developed by J. J. Lamb and described in several *QST* articles (August, 1932; March, June and November, 1933).

As shown in the filter portion of the diagram of Fig. 530, the variable parallel impedance of the input transformer secondary in series with the crystal (which is equivalent to a high-Q electrical circuit) effects variation in the effective resistance in the crystal circuit, thereby varying the selectivity in accordance with the principles of resonant circuits discussed in Chapter Four. The applied voltage is proportional to the parallel impedance, increasing as the effective resistance increases, so that the effective sensitivity of the receiver for a single-frequency signal is but little affected over a selectivity (band-width) range of approximately 10 to 1. Minimum selectivity occurs, of course, with the parallel circuit tuned to resonance, when it is purely resistive, and maximum selectivity when the parallel circuit is tuned to be considerably reactive. The crystal is connected in a bridge circuit to provide counter voltage of controllable phase, through an adjustable condenser, so as to modify the resonance curve and shift the anti-resonant frequency of the crystal, thus giving particular rejection for an unwanted signal (of a frequency from several kilocycles above to several kilocycles below the crystal's resonant frequency), in addition to the sharply peaked response given for the desired signal.

Automatic Gain Control

With the wide variation in signal strength and severe fading encountered in high-frequency reception there is considerable advantage in automatic gain (or volume) control in the receiver, with the receiver gain governed by the strength of the received signal. Such a system is applicable for 'phone reception, with a continuous carrier, but is not usefu for amateur c.w. reception where the carrier is intermittent. Although there is a wide variety of a.g.c. systems, all operate on the same principle; namely, that rectified and filtered carrier voltage is used to provide inversely varying bias for the r.f. amplifier tubes of the receiver. This bias may be obtained from the detector circuit (*QST*, November, 1933), or from a separate tube having its grid excited by r.f. bled off from the second-detector input. Typical examples are shown in Figs. 528 and 530.

Manufactured Superhets

Because many amateurs now purchase manufactured amateur-type superhet receivers in preference to constructing their own, brief descriptions of three representative models are included in this chapter. Plan views and circuit diagrams are shown for reference in servicing and checking.

Fig. 525 illustrates the amateur-type National FB7A superheterodyne. Immediately behind the horizontal h.f. oscillator plug-in coil shield (left) is the oscillator tube; behind the first detector coil shield (right) is the first detector tube. Behind these, in line from right to left, are the first i.f. transformer, first i.f. tube, second i.f. transformer and second i.f. tube. The second detector tube is in the rear-left corner, with the c.w. oscillator's shielded tank circuit, c.w. oscillator tube and pentode audio output tube to its right. Immediately below the vernier tuning knob is the projecting edge of the horizontal volume control disc. Above the tuning control is the frequency calibration chart for the amateur bands. To the right of the oscillator-first detector tuning condenser gang (center) is the trimmer for the first detector tuning which is set once for all ranges. Individual trimmers are included in each coil assembly, with screwdriver adjustment through the front end of the coil forms.

Fig. 526 shows the circuit of the FB7A receiver In this diagram, and in the two following, figures adjacent to condensers indicate capacitance in

μfd., those next to resistors indicate resistance in ohms. Values are given for assistance in servicing and are not intended as specifications for construction. Lettered values are as follows: C_1, 105-μμfd. variable condensers; C_2, coil trimmers, varying with type of coil, between 2-μμfd. and 115-μμfd; C_3, 2-μμfd. oscillator coupling condensers; C_4, 70-μμfd. air-type i.f. tuning condensers. This receiver is intended for a.c. operation from a separate power pack furnishing 2.8 volts a.c. and 180 to 250 volts d.c., the latter being recommended for maximum sensitivity and loudspeaker output. The i.f. is 495 kc.

The Hammarlund Single-Signal type "Comet Pro" with quartz crystal i.f. filter and automatic gain control is shown in Fig. 527. The first-detector plug-in coil ("W.L.") is housed by the large shield immediately behind its tuning condenser, to the right of the drum dial; the h.f. oscillator coil ("Osc.") and tuning condenser are similarly located at the left. The respective tank padding condensers are on the front panel, right and left of the dial. The h.f. oscillator tube is to the left of this assembly, the first detector to the right near the panel. The i.f. filter crystal assembly is on a small panel behind the main panel (not visible) with its input and output transformers in the shield at the front-right corner. To the rear of this are, in order, the second and third i.f. transformers, and the c.w. oscillator tank circuit. To their left are the first and second i.f. tubes, and the second detector, with the c.w. oscillator tube at the extreme rear. Behind the plug-in coil shields are the a.g.c. tube and its plate transformer. The receiver's power pack is at the left side, with the rectifier tube socket left of the a.g.c. transformer. The pentode output tube socket is the one remaining, near the antenna terminal strip (right) and speaker terminals (left) at the rear edge of the chassis. On the panel, in addition to the tuning controls, are (left to right) the tone control, 'phone jack, combined audio volume control and power switch, beat oscillator switch, manual gain control, the a.g.c. switch, filter switch and filter "elimination" control. A metal cabinet houses the chassis.

FIG. 525

Fig. 528 is the circuit of the "Comet Pro" with crystal filter and a.g.c. In the 465-kc. i.f. filter, step-down input and step-up output transformers provide practically constant low impedance in the crystal circuit. The crystal is shorted by the switch for straight superhet operation. The elimination-control condenser operates to shift the anti-resonant frequency of the crystal to reject an unwanted carrier, with the crystal in circuit.

Amplified automatic gain control for 'phone reception is provided by the 2B7 tube which acts as a combined r.f. amplifier and diode rectifier. Its control grid is coupled to the output of the second i.f. stage. Amplified i.f. energy in its plate circuit is coupled to the diode circuit by the tuned-primary transformer. Rectified r.f. voltage developed across the resistor-condenser connected between the secondary of this transformer and ground is applied to the control grids of the i.f. amplifier tubes through their return circuits, varying i.f. gain inversely as the carrier strength. The manual gain control

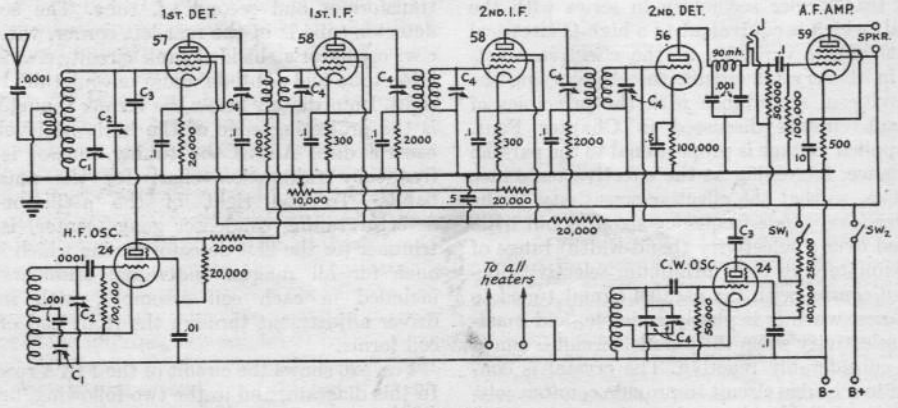

FIG. 526

is simultaneously operative to set the maximum sensitivity. The a.g.c. is cut off by the switch shorting the grid-return circuit to ground.

Fig. 529 is a rear view of the National AGSX single-signal type superhet with preselector, variable-selectivity i.f. filter and automatic gain

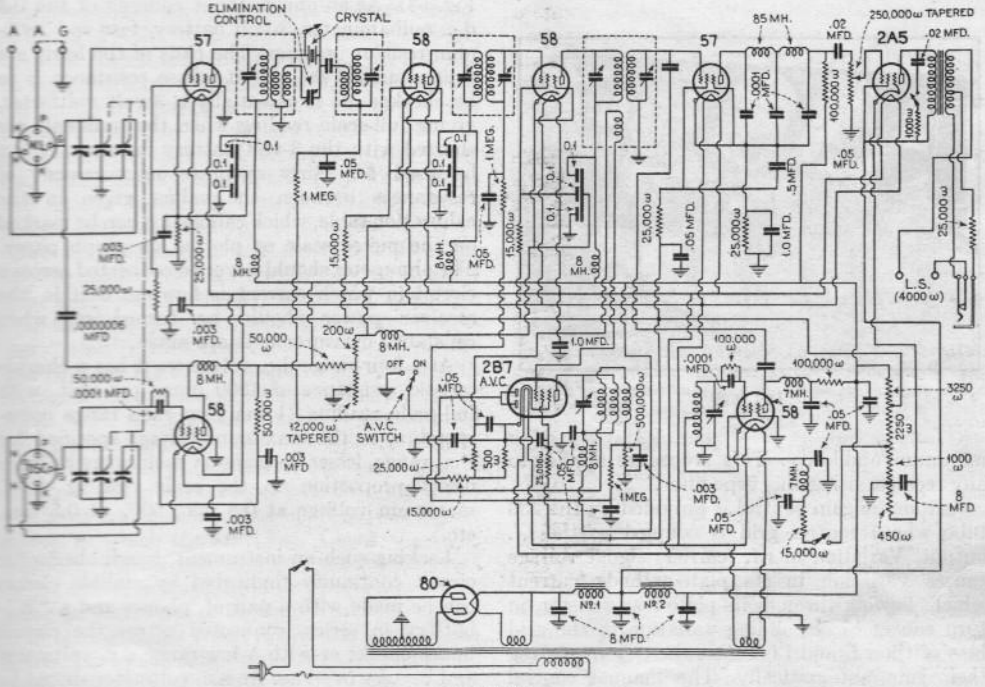

FIG. 527

control. The three variable tuning condensers of the h.f. circuits (r.f., first detector and oscillator) are contained in the shielded compartment and are driven by a rack-and-pinion mechanism operated by the main dial. The coils, which plug in from the panel front, are individually shielded in the horizontal cans. The pre-selector coil assembly is at the right, the oscillator in the center and the first detector at the left, the respective tubes being immediately below the coil shields. The i.f. filter circuit is at the left of the assembly, next to the panel. The i.f. circuits progress thence to the rear of the chassis and to the right, where are the c.w. beat oscillator and output stages. The beat-oscillator frequency control condenser is on the panel at the right. This model is intended for mounting on a standard 19-inch relay rack.

The circuit of the AGSX Receiver, Model F., is shown in Fig. 530. The circuit is generally conventional with the exception of the 495-kc. i.f. filter and a.g.c. circuits. H.f. circuit constants are as in Fig. 526. The filter is of the variable bandwidth type, operating as explained earlier in the chapter. A switch shorts the crystal (for straight superhet operation), or connects it in parallel or in series, the latter for full single-signal operation. A panel control operates the double-section condenser to vary selectivity with the crystal in series. To align the i.f. transformers in this type receiver, the plug-in crystal is removed and connected in a 495-kc. crystal oscillator circuit of conventional type which serves as the test oscillator. The adjustments of i.f. transformer tuning are made with the filter switch in the "off" position, of course,

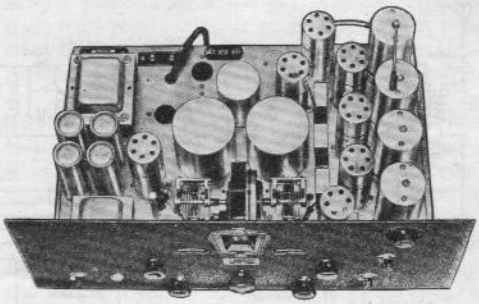

FIG. 528

the alignment procedure being the same as has been described for conventional superhets. With the crystal back in the filter circuit, a steady signal of local origin is tuned in precisely on resonance and the c.w. beat oscillator adjusted to a

frequency of about 1000 cycles above i.f. resonance, as indicated by the beat note. The receiver is then tuned "through zero beat" to a setting which gives an identical beat note "on the other side." The phasing condenser (rejection control), to the right of the filter in the rear view, is then adjusted to make this "audio image" signal of

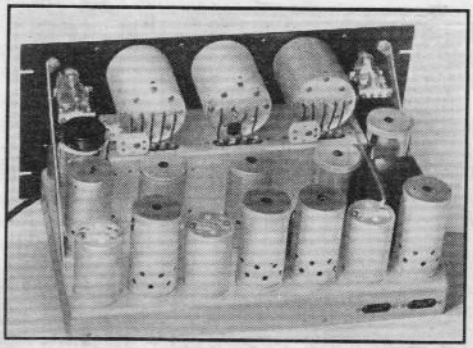

FIG. 529

minimum audibility. This procedure applies to any receiver using this type filter.

Automatic gain control is provided by the 236 tube whose control grid is coupled to the i.f. output. Variation in r.f. (carrier) signal voltage causes variation in its plate-cathode current which, flowing through its plate load resistor, in turn causes corresponding variation in the grid bias of the r.f. and i.f. tubes, thereby regulating their gain automatically. The manual control operates to set the bias on the a.g.c. tube, thus allowing adjustment for desired maximum sensitivity with the a.g.c. in operation; or giving complete manual control with the a.g.c. switch in the "M.V.C." position.

Trouble Shooting

The most useful instruments for locating faults in a defective receiver are a multi-range ohmmeter and a high-resistance d.c. voltmeter. A simple combination ohmmeter and d.c. voltmeter suitable for general receiver testing is diagrammed in Fig. 531. As an ohmmeter it consists of the 0-1 d.c. milliammeter, 3-volt battery, fuse and 2800-ohm resistor in series. The ends of the leads are tapped across the circuit whose resistance is to be checked. It is essentially a 3-volt voltmeter, giving full-scale reading when the terminals are shorted with the 3-volt battery in series. It can be used for fairly accurate measurement of resistances between the values given in the calibration table, which calibration can be marked on the meter scale or plotted on graph paper. The ohmmeter should never be connected across a circuit in which current is flowing; that is, the receiver power should be turned off when resistance measurements are made.

As a four-range d.c. voltmeter it has a characteristic resistance of 1000 ohms per volt, with full-scale reading (1 ma.) on each range corresponding to the maximum voltage specified for that range, lesser voltages on each range being in direct proportion to the scale reading (80% maximum voltage at 0.8 ma., 50% at 0.5 ma., etc.).

Lacking such an instrument, rough checks for circuit continuity (indicated by audible clicks) can be made with a pair of 'phones and a "B"-battery in series, connected across the circuit under check; or with a low-range d.c. voltmeter and battery in series. An a.c. voltmeter should be used for checking the line and filament voltages in a.c. operated sets.

If the tubes do not light, check the filmament supply (transformer or battery) and connections. Zero voltage across the primary will result with a

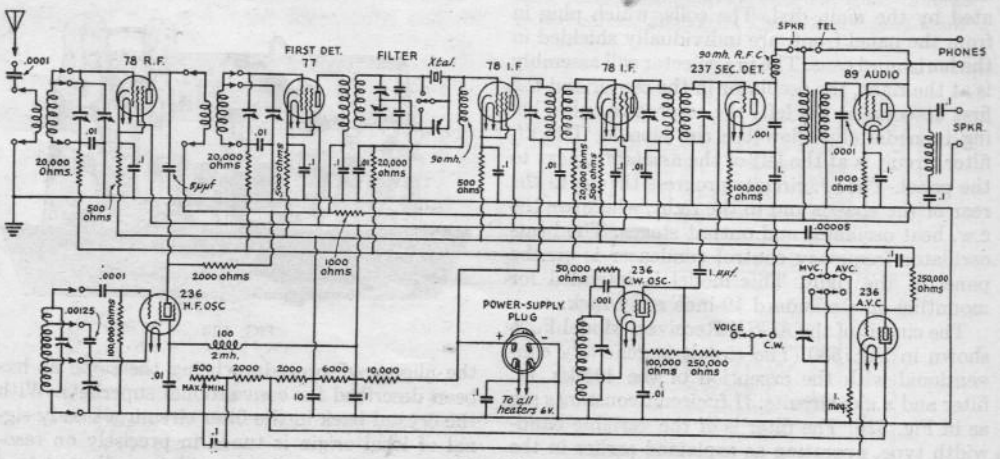

FIG. 530

blown fuse in the primary of an a.c. supply. Check the voltage at the socket terminals of a single tube that fails to light when others come on. If voltage checks OK, the tube may be burned out or there may be a defective contact in the socket.

Unreasonable hum in an a.c. receiver usually indicates either an open filament center-tap resistor or a tube with low resistance (leakage) between heater and cathode. Such a tube should be replaced. Less likely causes of excessive hum are an open filter or by-pass condenser in the supply circuits, or a defective rectifier tube. An open receiving tube grid circuit also may cause bad hum, usually accompanied by low output and serious distortion. Periodic clicking accompanied by poor sensitivity in a regenerative receiver may indicate an open detector grid leak or one of excessively high resistance. Replace the leak, using one of lower resistance if necessary.

If the filaments light but there is no output (set "dead"), first check the B-supply voltage and connections to the output stage. Even with no signal coming through there should be strong clicks when the headset or speaker is connected and disconnected. If the output circuit checks OK, clip a pair of 'phones across the output of each preceding audio stage, including the detector, until the signal is picked up, thus locating the circuit in which the fault lies. Check the tube, resistors, bypass and coupling condensers, etc., in the defective stage, both for shorts and opens, using an ohmmeter or its equivalent.

If strong clicks result when the grid of the detector is touched, but there is no signal or only very weak signal output, it is likely that the fault is in a r.f. circuit ahead of the detector. Check the r.f. tube or tubes and the plate circuits of preceding stages for opens and shorts. An open secondary circuit or grid coil may cause periodic clicking like that resulting from a defective detector grid leak, in which case the grid circuit should be tested for open circuit with an ohmmeter or 'phones and battery. If a circuit should test neither shorted nor open but does not "tune," look for a defective connection between coil and tuning condenser.

Noticeably weak signal response will result with an open antenna coupling coil or open connection in the antenna-ground circuit. A shorted grid condenser, either in a detector circuit or a r.f. amplifier using capacitive coupling, will have the same effect. This may be checked by removing the grid resistor, which should cause the periodic clicking sound in the output. Shorts of this kind can be caused by a blown condenser or by soldering paste smeared between the terminals. Needless to say all soldered connections should be thoroughly wiped with a clean cloth to prevent such leakages.

A regenerative receiver may "howl" just as the detector starts to oscillate. This "fringe howl" is most likely to result with transformer or impedance-coupled detector output and the best precaution against it is to use an audio transformer or choke of the better grade rather than one of the cheaper type with inadequate primary windings. If it does occur with the transformer that must be used, however, it can be reduced or

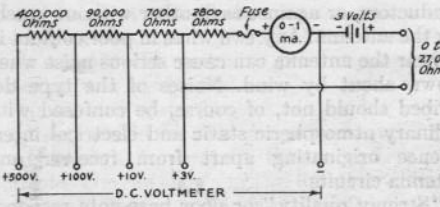

FIG. 531 — A COMBINATION OHMMETER AND D.C. VOLTMETER SUITABLE FOR RECEIVER TESTING

It may be assembled on a Bakelite panel in an instrument case. The 0–1 ma. d.c. milliammeter should be of the low-resistance type. Two flash-light cells in series serve as the battery. The resistors preferably should be "precision" type. A 1/100-amp. low-voltage type Littelfuse should be connected as shown. If it is omitted, the 2800-ohm resistor should be replaced by one of 3000-ohms. The approximate ohmmeter calibration is as follows:

Meter Scale (Ma.)	Ohms	Meter Scale (Ma.)	Ohms
1.0	0	.375	5000
.96	100	.30	7000
.85	500	.25	9000
.75	1000	.20	12,000
.60	2000	.15	17,000
.50	3000	.10	27,000

eliminated by connecting a resistor across the secondary of the audio transformer. In most cases a resistance of 100,000 ohms will be sufficiently low. A grid leak of lower value also may help in some cases. These expedients reduce the receiver output, of course, and must be considered as less desirable than the substitution of an audio coupler having better characteristics.

"Scratching" noises that persist when the receiver is untouched by the operator may have several sources. In a battery operated receiver they may result with A or B batteries in poor condition, either because of a defective (high-resistance) cell or cells, or because the batteries are nearly run down. The batteries should be checked with a voltmeter, while the receiver is turned on. Dry batteries should be replaced when the voltage becomes about 80% of normal rating. "Scratching" noise also can be caused by poorly soldered connections, loose lug terminals, a partially open resistor, a "leaky" condenser or defective tube socket contacts. Locate by moving the wiring with a piece of stick, by checking resistors and condensers with an ohmmeter and by "wobbling" the tubes in the sockets with the receiver turned on. In some cases noises of this type is caused, when the receiver controls are manipulated, by a metal shaft or dial rubbing against the panel or some other metal object. If also may result from dirt between the plates of a variable

condenser or a poor contact in a variable condenser or resistor. The latter types usually can be located by inspection.

If the "scratching" ceases when the antenna and ground are disconnected its source is probably outside the receiver, possibly in the antenna system (poor connections) or in other metallic objects touching or rubbing against the antenna conductors, or against each other without touching the antenna. Any two wires in poor contact in or near the antenna can cause serious noise when blown about by wind. Noises of the type described should not, of course, be confused with ordinary atmospheric static and electrical interference originating apart from receiver and antenna circuits.

"Stringy quality" or poor base-note response usually can be traced to an open or inadequate bypass capacitance in a detector or audio amplifier circuit. Too-small capacitance across a cathode resistor is a common source. An open or too-small grid condenser in a grid-leak detector also may be the cause of this trouble.

Servicing Superheterodyne Receivers

In addition to the general receiver servicing suggestions given in the preceding section, there are a few others for troubles peculiar to superhet type receivers. Generally poor performance, characterized by broad tuning and poor sensitivity, calls for checking of the circuit tuning and alignment as previously described in connection with the adjustment of the five-tube receiver. The procedure is to start with the receiver output (audio) and work back through the second detor, i.f., and high-frequency circuits, in the order named.

In case of oscillation in high-frequency amplifier and first detector circuits, as evidenced by squeals or "birdies" with varing of their tuning, look for poor connections in the common ground circuits, especially to the tuning condenser rotors. Inadequate or defective bypass condensers in cathode, plate and screen grid circuits also can cause such oscillation. In some cases it may be advisable to provide a baffle shield between the stators of pre-r.f. amplifier and first detector ganged tuning condensers, in addition to the usual tube and inter-stage shielding. Improper screen-grid voltage, as might result with a shorted or too-low screen-grid series resistor, also could be responsible.

Oscillation in the i.f. circuits, independent of high-frequency tuning and indicated by a continuous squeal when the gain is advanced with the c.w. beat oscillator on, will result from similar defects in i.f. amplifier circuits. Inadequate cathode resistor bypass capacitance is a very common cause of such oscillation. Additional bypass capacitance, 0.1 to 0.25 μfd., usually will remedy this type of oscillation. The same applies to screen-grid bypasses of i.f. tubes.

"Birdies" and "mush" occurring with tuning of the high-frequency oscillator may indicate that it is "squegging" or oscillating simultaneously at two frequencies. This may be caused by a defective tube, too-high oscillator plate or screen-grid voltage, excessive feed-back in the oscillator circuit or excessive gridleak resistance. If the latter, replace with a new resistor, using one of lower resistance if necessary.

Excessive "hiss" may be caused by a defective h.f. or i.f. tube, by an open grid circuit, or by too-large first oscillator r.f. input to the first detector circuit. The first oscillator plate (or screen) voltage should be no greater than that necessary for good signal response and the coupling between oscillator and first detector should be the minimum required. It may be helpful to reduce the oscillator screen voltage, in the case of an electron-coupled oscillator, or the plate voltage in the case of a triode. The same symptoms and remedies apply to the c.w. beat oscillator and its coupling to the second detector. There should be some increase in hiss when the latter is switched on, of course, as a result of the i.f. noise components beating with the carrier it furnishes in the second detector. The oscillator input to the second detector should be just enough to cause a noticeable change in second detector plate current. (About 0.05 ma. increase in the case of a self-biased triode second detector, for instance.)